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THE JULY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

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THE SCIENTIFIC MONTHLY

JULY, 1934

THE PLANETS AND THEIR ATMOSPHERES

By Dr. WALTER S. ADAMS

DIRECTOR, MOUNT WILSON OBSERVATORY OF CARNEGIE INSTITUTION OF WASHINGTON

THROUGHOUT the years since primitive man first raised his eyes to the heavens and saw the evening star the planets, called by the Greeks the wandering stars, have held remarkable interest for the human mind.

Apart from their beauty, the mystery of their motions and of their changing brightness has made a constant appeal through the centuries to man's curiosity and love of discovery. After Copernicus and Galileo the knowledge of the relationship of the planets to our earth as common children of the sun, with a similar history, and the prospect of a similar fate, has continued to stir the imagination.

So it is by no means strange that the planets have figured so greatly in poetry and literature, nor even that among the absurdities of astrology we find crude expression of the permanent interest attaching to the members of our solar family.

In recent years with the growth in our knowledge of the universes of stars it is with something of the feeling of a traveler returning to his home after a long journey that we turn back from the appalling distances and loneliness of space to the narrow limits governed by our sun. In much the same way we can picture Columbus counting the ships in the harbor of Lisbon after his lonely months upon the Atlantic.

SHIFT OF INTEREST

With the progress of human thought and discovery our interest in the planets has naturally turned more and more toward their physical characteristics and constitution. The earliest great problem was that of their motions and with its solution man gained an answer to many of the questions which had so long baffled him, the mystery of Venus as a morning and an evening star, the elusive glimpses of Mercury, now on one side of the sun and now on the other, and the strange motions of the outer planets which appear to move among the stars, then stop and retrace their steps.

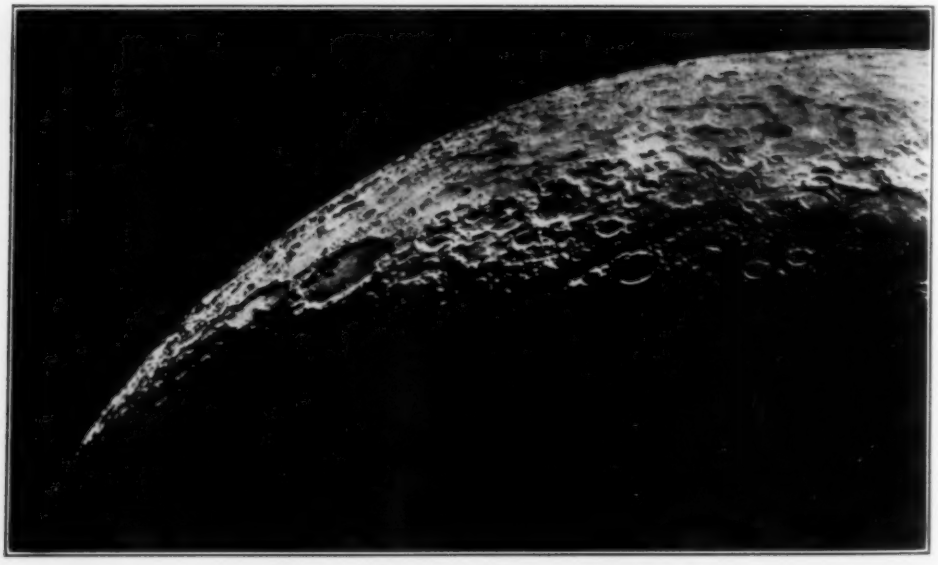
When the telescope and accurate methods of measurement were developed we rapidly gained a knowledge of their distances, their sizes, masses and forms. So our knowledge of the individual planets considered as astronomical bodies is very complete. Naturally the degree of accuracy varies with different planets. The mass of Mercury is uncertain within a considerable range, and in the case of Pluto we can do little more than form probable limits for its size and mass based upon considerations of brightness and the disturbances it produces in the motions of other planets. But in general our facts regarding the planets as a whole are very reliable.

Difficulties Affecting Study

It is quite different when we begin to consider the constitution of the planets, their atmospheres and the conditions prevailing on their surfaces. In the first place planets shine by reflected light and are not self-luminous. Hence the light we receive from a planet is simply sunlight modified to some degree by transmission through the planet's atmosphere in case such an atmosphere exists. Difficult as it is to realize, it is a much more serious problem to learn the composition of the surface of our satellite, the moon, the nearest object in the sky, than of a star the light of which may be thousands of years in reaching us.

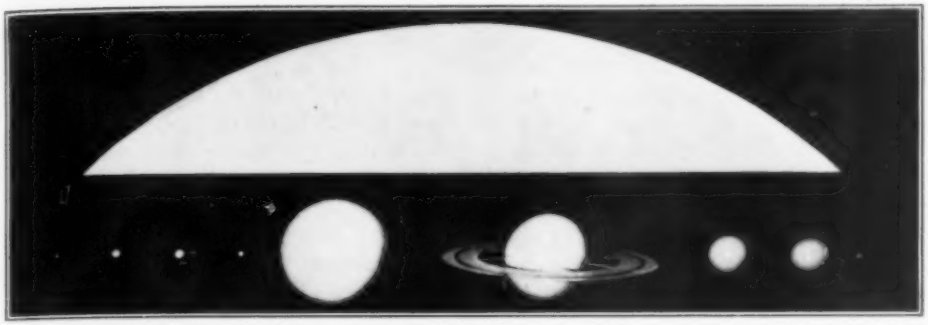
The gases of the elements composing the atmosphere of the sun or a star radiate or absorb their own characteristic light and give immediate evidence of their presence when the light is analyzed with a spectroscope, while the moon acts as a mirror and simply reflects the light it receives from the sun. In fact, almost all our knowledge of the nature of the material composing the surface of the moon is obtained through a study of the influence of reflection by different kinds of materials upon the plane of vibration of light waves, a phenomenon skilfully utilized by Dr. Wright, of the Carnegie Institution, to prove that the moon's surface can not consist of exposed rock, but must be covered by a layer of very fine sand or, more probably, volcanic or meteoric dust.

Much of our information regarding the planets must depend upon direct visual and photographic observations. Surface markings, the periods of rotation, clouds and varying features on the apparent surface, and to some extent the presence or absence of an atmosphere itself must all be studied with the telescope, and here we encounter the serious difficulty of atmospheric disturbances.



THE SOUTHERN PORTION OF THE MOON

TWENTY-SIX DAYS AFTER THE "NEW MOON" APPEARS; TAKEN WITH THE 100-INCH TELESCOPE AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. ON THE MOON THERE IS NO WATER VAPOR NOR ANY OTHER GAS TO EQUALIZE THE SUN'S RADIATION; CONSEQUENTLY ITS TEMPERATURE UNDERGOES ENORMOUS VARIATIONS, FROM THAT OF BOILING WATER ON THE SIDE TOWARDS THE SUN TO 250° BELOW ZERO, FAHRENHEIT, ON THE DARK SIDE.



SHOWING THE RELATIVE SIZE OF THE SUN AND PLANETS

FROM A PHOTOGRAPH OF THE MODELS PREPARED BY THE MOUNT WILSON OBSERVATORY FOR THE ANNUAL EXHIBITION OF CARNEGIE INSTITUTION, HELD IN DECEMBER, 1933. *Upper*—A SEGMENT OF THE SUN IN SCALE WITH THE PLANETS. *Lower* (FROM LEFT TO RIGHT)—MERCURY, VENUS, EARTH AND THE MOON, MARS, JUPITER, SATURN, URANUS, NEPTUNE, PLUTO.

ATMOSPHERIC DISTURBANCES

When a telescope is pointed to the sky it is looking out through the entire depth of the earth's atmosphere. Each irregularity in the temperature and density of the air through which the light passes bends and twists the beam of light, and as such irregularities change very rapidly there is a continual blurring and quivering of the image. This is the familiar twinkling of the stars so often seen on a windy winter night, and in a telescope the effect is increased in proportion to its magnifying power. Such a blurring effect goes far toward obliterating the surface details and finer markings on the planets or the sun and moon, and explains why astronomers seek to locate their observatories where the air is most steady and free from disturbance, and why Percival Lowell established his observatory, primarily for the study of Mars, on an isolated plateau in central Arizona.

It also answers the question most frequently asked of astronomers whether a telescope can not be built sufficiently large to bring the moon within a few miles and Mars within a few hundreds of miles and so make even the smallest details visible. There is ample light for such observations with existing telescopes, and the magnifying power may be made as high as may be desired, but unfortunately the disturbances due to the earth's atmosphere are magnified along with the planet's disk and nothing is gained.

If the earth's atmosphere could be removed the astronomer could use a compound microscope attached to his telescope to view the moon, and the limit of magnification in the case of the planets would be set only by the resolving power of his telescope and the disturbances in the atmospheres of the planets themselves.

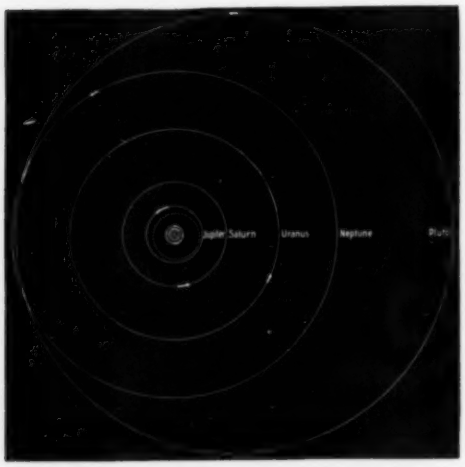
These difficulties affecting observations of the planets explain in part why our knowledge of their physical state is less complete than our knowledge of them as astronomical bodies. Much has been learned, however, and much more may be expected with the development of new and more sensitive instruments for measuring radiation and for studying the influence of the atmospheres and the surface materials of the planets upon the quality of the reflected light.

FACTORS GOVERNING CONDITIONS

There are three important factors which govern to a large extent physical conditions upon a planet and what we

may call its climate. The first is, of course, its distance from the sun. This determines the amount of heat and light which it receives, a quantity which varies for each unit of area as the square of the distance. Thus Neptune, which is thirty times as far away from the sun as the earth, receives only one nine-hundredth as much light and heat on equal areas of its surface.

The second factor is the length of the planet's day, its period of rotation on its axis. This regulates the amount of time during which the sun's heat falls on different portions of the surface. The more



SHOWING THE PLANETARY ORBITS FOR 1933, IN SCALE

IN THIS REPRESENTATION THE ORBITS OF THE INNER PLANETS, MERCURY, VENUS, EARTH AND MARS, ARE TOO SMALL TO BE READILY DISTINGUISHED WITHOUT A HANDGLASS. THE LENGTH OF THE ARROW ON THE ORBITS OF THE OUTER PLANETS, JUPITER, SATURN, URANUS, NEPTUNE AND PLUTO, REPRESENTS THE DISTANCE TRAVELED BY THE PLANET IN ONE YEAR.

rapidly a planet rotates the more nearly uniform will be the amount of heat received by all its parts.

An extreme case is that of Mercury, which is generally believed to rotate in the same period of 88 days in which it revolves about the sun. Hence the planet always turns the same face to the sun, as does the moon to the earth, and one side is intensely heated by the powerful solar radiation, while the other side never receives any sunlight and must be extremely cold.

The third consideration which bears especially upon the question of planetary atmospheres is that of the masses of the planets. We do not know definitely that all the planets originally had atmospheres, although this seems probable, but if they did several of the planets would have lost them either completely or in part because they were not massive enough to retain them.

The molecules composing the gases of an atmosphere are constantly flying about with high velocities, colliding with one another and rebounding in all directions. These velocities are highest for the lightest gases like hydrogen and helium and lower for the heavier gases like oxygen and nitrogen. Furthermore, the velocities are increased by increase of temperature. As a result, if a rapidly moving molecule in the upper part of a planet's atmosphere where collisions are infrequent is not attracted by the planet with a force sufficient to counteract its velocity of escape, it will fly off into space and be lost.

So a planet has to have a considerable mass in order to retain its atmosphere and especially to hold the lighter gases like hydrogen and helium which would be the first to escape. In the earlier stages of their history when the planets were probably much hotter the rate of escape for all gases must have been much more rapid.

Masses Compared

If we compare the results of observation with what might be expected from theory, we find remarkably good agreement. Mercury with a mass about one twentieth that of the earth has no atmosphere, while Venus with nearly the mass of the earth has an extensive atmosphere.

The earth has probably lost some of its free hydrogen but shows a small amount of helium and abundance of the heavier gases like nitrogen and oxygen. Our satellite, the moon, with one eightieth the mass of the earth, has no atmosphere, and on Mars, with one tenth the earth's mass, the atmosphere is thin and of low density.

On the other hand, the giant major planets with masses ranging from 15 times the mass of the earth, in the case of Uranus, to over 300, in the case of Jupiter, have dense and extensive atmospheres. They have doubtless retained all their original gases, including hydrogen and helium, the gravitational attraction of their great masses binding the molecules of the gases firmly to the planets.

Evidence of Atmosphere

The presence of an atmosphere around a planet is usually detected from observations of clouds and variable markings, or, as in the case of Venus, from the extension of the horns of the crescent beyond the diameter of the planet, owing to the diffuse reflection of light in the planet's atmosphere—an effect similar to our twilight.

For our knowledge of its composition we must then depend upon the spectroscope, which analyzes the light and shows what modifications the sunlight has undergone in passing through the atmosphere. These usually occur in the form of bands and lines which are due to the absorption of the cold molecules of gas and appear for the most part in the red and infra-red portions of the spectrum.

The most prominent in the earth's atmosphere are those due to oxygen, water vapor and carbon dioxide. Ozone produces a few faint lines in the yellow portion of the spectrum, but its principal bands lie in the ultra-violet and are so strong that they set a definite limit to the extent of the spectra of the sun and stars. Astrophysically this is most unfortunate, but, as Dr. Abbot and others have emphasized, life could hardly exist upon the earth if exposed directly to this highly penetrating radiation from the sun.

Since the surfaces of planets must be observed not only through their own atmospheres but through that of the earth as well, the bands and lines due to our atmosphere are always present in the spectra of the planets. There are two ways in which the effect due to the earth may be separated from that due to the planet, and the relative abundance of the gases in the two atmospheres may be determined.

The first is by comparing the intensities of the bands in the spectrum of the planet with those obtained from light transmitted through the earth's atmosphere alone. For example, the spectrum of Mars, in which the light from the sun has passed first through the planet's atmosphere to the surface, then outward from the surface toward the earth, and finally through the earth's atmosphere, is compared with the spectrum of the moon, which has no atmosphere.

If the altitude of the moon in the sky is the same as that of Mars the length of path through the earth's atmosphere is the same in both cases, and any excess of intensity in the lines of the spectrum of Mars must be ascribed to the gas in the planet's atmosphere. Allowance must, of course, be made for the double path of sunlight through the atmosphere of the planet which should increase the intensity of the planetary lines.

A second method of separating planetary lines from those of terrestrial origin depends upon the fact that the motion of a planet toward or away from the earth produces a displacement of the spectral lines. Accordingly if a time is selected when a planet is approaching or receding rapidly from the earth and the spectrum can be photographed on a sufficient scale the planetary lines will ap-

pear completely separated from those due to the earth's atmosphere. This method has marked advantages over that in which measurements are made upon the intensities of the superposed lines, but both methods have been used in the study of planetary spectra, especially those of Venus and Mars.

Measuring Temperatures

The second important means for investigating physical conditions on the planets is through direct measurements of temperature. Such methods have developed out of the remarkable improvements in the construction of sensitive heat-recording electrical instruments. Dr. Pfund and Dr. Coblentz were among the pioneers in this field, and Coblentz and Lampland, of the Lowell Observatory, made some of the first and most accurate observations of planetary temperatures.

Several different types of instruments are available, but that which has been used most extensively contains a thermocouple as the heat-sensitive element. It depends upon the fact that when the junction between certain metals is warmed an electric current is set up which may be measured with a sensitive galvanometer. For most astronomical purposes bismuth and an alloy of bismuth with a small amount of tin have been used, and the dimensions of the thermocouple as well as of the receivers, the thin strips of metal upon which the image of the planet or the star falls, are made almost incredibly small. The entire weight of some of the compensated thermocouples used by Pettit and Nicholson at Mount Wilson, including the receivers and their connections, is about one thousandth part of that of a drop of water.

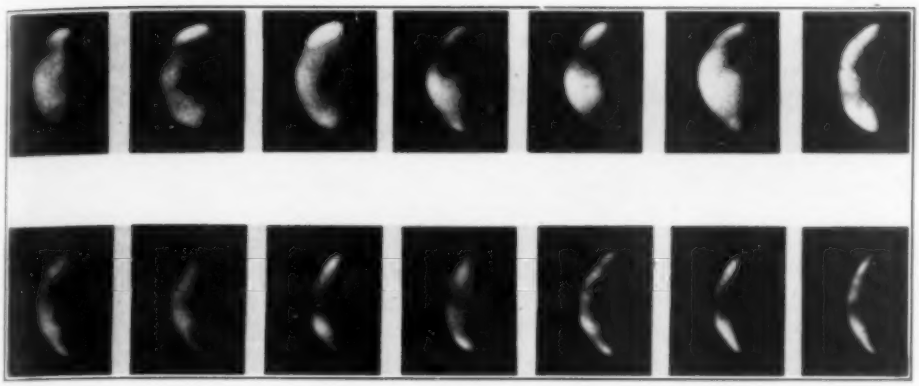
The thermocouple is placed in a high vacuum which increases its sensitiveness greatly, and during the observations the image of the star or planet is thrown alternately upon one receiver and then upon the other so that the effect of the measured heat is doubled. The receivers, which are about one fiftieth of an inch in diameter, are so small that details of planetary surfaces, such as the polar caps and the dark and bright markings on the surface of Mars, can be studied individually.

With such an instrument, a rise in temperature of the receiver of three hundred-thousandths of a degree is measured without difficulty, and the heat of stars invisible to the naked eye has been determined with the aid of the 100-inch telescope.

When a planet receives radiation from the sun a part is reflected directly away in the form of reflected sunlight and a part is absorbed and warms the planet and is re-radiated in the form of long heat waves. This radiation is that which determines the temperature of the planet. Accordingly, two sets of measures are made, one through a thin plate of glass which absorbs most of the planetary radiation and the other with the glass plate removed. In this way the amount of heat emitted by the planet itself is determined, and through application of the law connecting temperature with radiation, with due allowance for the absorption by the earth's atmosphere, the temperature of the planet is calculated.

We may now pass to a consideration of the results found for the individual planets. Beginning with Mercury, which has a mean distance from the sun only about one third that of the earth, we find a planet of small mass exposed to intense heat from the sun, and, as we have already seen, always turning the same face toward it. Both visual and spectroscopic observations agree in showing that it can have no appreciable atmosphere, a conclusion which is confirmed by its appearance when observed crossing the disk of the sun as a small black spot during one of its transits.

The temperature on the surface



FROM ULTRA-VIOLET PHOTOGRAPHS OF VENUS

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. UPPER SERIES—TAKEN IN JUNE. LOWER SERIES—TAKEN IN JULY. VENUS BEARS CLOSE COMPARISON WITH THE EARTH IN MANY RESPECTS, HAVING NEARLY THE SAME SIZE AND DENSITY AND ABOUT NINE TENTHS THE SURFACE GRAVITY. IT HAS AN EXTENSIVE ATMOSPHERE, LESS DENSE THAN THAT OF THE EARTH, AND A PERMANENT LAYER OF CLOUDS WHICH PREVENTS ITS SURFACE CONDITIONS FROM BEING KNOWN. CARBON DIOXIDE GAS IN LARGE QUANTITIES IS PRESENT IN ITS UPPER ATMOSPHERE, BUT OXYGEN AND WATER VAPOR APPEAR TO BE ABSENT FROM THE REGION ABOVE THE CLOUD LEVEL FROM WHICH THE LIGHT IS REFLECTED.

turned toward the sun is extremely high, about 600° Fahrenheit or higher than the melting point of lead. On the side turned away from the sun the temperature has not been measured but must be very low. The planet has certain dark permanent markings, and its surface is probably as rough as that of our moon. Our conception of the surface of Mercury must be that of a desert-like area, intensely hot on the illuminated side and extremely cold on the dark side, with no possibility of change in its features except through the slow processes of disintegration due to temperature.

VENUS HAS AN ATMOSPHERE

When we pass to Venus, the Hesperus of the Greeks, and the brightest of all the planets in the sky, we find quite different physical conditions. Its average distance from the sun is nearly three fourths that of the earth and its mass about four fifths as great. In many respects it is almost a twin to the earth, having nearly the same size and density and about nine tenths the surface gravity. An object weighing 100 pounds on the earth would weigh 85 pounds on Venus.

It has an extensive atmosphere, probably considerably less dense than that of the earth and is surrounded by what appears to be a perpetual layer of clouds. It is doubtful if we ever see the actual surface of Venus, the few vague markings which have been observed being quite possibly areas where the clouds have temporarily dissolved into a thick haze, much as fog dissolves over the earth. This cloud layer unfortunately prevents us from carrying our observations of temperature and atmospheric composition to the surface of the planet, and even the rotation period of the planet is very uncertain.

In the absence of permanent surface markings the only method of deriving the length of the day on Venus is from observations with the spectroscope. The rotation of the planet would cause one edge of the disk at the equator to approach us and the other to recede from us and thus should produce an inclina-

tion of the spectral lines. Several observers have made careful measures of the spectrum of Venus but have been unable to detect any appreciable inclination. This would indicate that the rotation period of Venus must be long, at least several days, although probably not so long as its period of revolution about the sun.

Quantities of Carbon Dioxide

Two interesting results have been found from spectroscopic studies of the light reflected from Venus. The first is the absence of any appreciable amount of oxygen and probably of water vapor above the cloud level from which the light is reflected; and the second is the presence of carbon dioxide gas in large quantities in this region of the atmosphere.

The intensity of the carbon dioxide bands is such as to correspond to a length of path of the order of half a mile through this gas at atmospheric pressure. It is, of course, quite possible that considerable amounts of oxygen and water vapor exist in the atmosphere of Venus below the cloud level which forms the limit of penetration of the spectroscope, although in the case of oxygen, at least, we should expect some spectroscopic evidence if conditions were at all analogous to those above high clouds in the atmosphere of the earth.

As all know, plant life consumes carbon dioxide and gives out free oxygen, and the suggestion has repeatedly been made that the free oxygen in the earth's atmosphere is wholly of vegetable origin. If, as Russell suggests, any original free oxygen in the atmosphere of Venus was exhausted in the oxidation of the rocks of the surface and plant life did not develop, we should find here an explanation of the existing spectroscopic evidence. Since we are ignorant of conditions below the cloud layer on Venus, such a hypothesis is necessarily speculative.

Nearly all astronomers agree, however, that on general considerations Venus should be better fitted than any other planet for the existence of such life as is known upon the earth.

Temperature of Venus

Measurements of the temperature of Venus, like the spectroscopic observations, are limited to the level in the atmosphere above the cloud layer and can not give us information regarding temperatures on the surface of the planet. There seems to be some evidence that in the atmosphere of Venus, as in that of the earth, an isothermal layer or stratosphere exists where the temperature is not far from uniform throughout a considerable depth.

This temperature in the case of Venus is about 25° below zero Fahrenheit, 40° warmer than that for the earth. The fact that temperatures of the same order are found for the illuminated and the dark sides of Venus is an argument against a very long period of rotation, at least one approaching the 225-day period of revolution about the sun. The temperature at the surface of Venus is doubtless much higher than that of the upper levels of its atmosphere and probably is also higher than that of the surface of the earth.

Conditions on the Moon

The next planet in order of distance from the sun is the earth with its attendant satellite, the moon. The temperature of the moon with no atmosphere to blanket and equalize the sun's radiation and with its long period of rotation is subject to enormous variations. The surface exposed directly to the sun's heat reaches a temperature close to that of boiling water, while that of the dark side is about 250° below zero Fahrenheit. The effect of the absence of an atmosphere and of the low heat conductivity of the materials of its surface is strikingly shown by temperature

measurements at the time of a lunar eclipse.

During the partial phase the temperature drops very rapidly, then slowly during totality, remains nearly stationary for a few minutes and then rises abruptly as the shadow passes away. The large differences of temperature between day and night so familiar to us on a desert on the earth are due mainly to the low humidity of the air, since the presence of water vapor serves to reduce the sun's heat during the day and to lessen the radiation from the earth during the night. On the moon where there is neither water vapor nor any other gas we find an extreme case of such conditions, the surface heating and cooling with extraordinary rapidity.

The Earth's Atmosphere

It is unnecessary to comment extensively upon the earth or its atmosphere. There are, however, one or two facts of interest which should be considered in relation to the planets in general.

The mean temperature of the whole earth is 57° Fahrenheit and of the tropical zones about 79°. The composition of dry air at the surface of the earth is about 78 per cent. nitrogen, 21 per cent. oxygen and 0.9 per cent. argon, with very small quantities of carbon dioxide, ammonium, hydrogen, helium and other gases. In moist air the amount of water vapor may exceed one per cent. As we go to higher levels in the atmosphere these percentages change very rapidly and above 50 miles the atmosphere theoretically should be composed almost wholly of hydrogen.

It is not known, however, whether any such amount of hydrogen actually exists nor can its presence be detected spectroscopically as in the case of oxygen, water vapor and carbon dioxide. The mass of the earth is sufficient to retain a hydrogen atmosphere almost indefinitely, but the question whether it is present or not must await methods of study of the upper atmosphere which we do not as yet possess.

The Earth as Seen from Planets

An interesting question regarding the earth is its telescopic appearance as seen from other planets. About half of the earth's surface, on the average, is covered with clouds and these would appear as conspicuous areas because of their high reflecting power. The seas and other large bodies of water would shine brilliantly when reflecting sunlight directly to the observer, but would be dark when seen at less favorable angles. Snow- and ice-covered areas, varying with the seasons, would be prominent, and large forested regions, deserts and grass land could probably be detected by their differing colors.

All the surface features, however, would have to be viewed through the depth of the earth's atmosphere with its dust and haze and all the effects of scattering and reflection of light which it produces. The result, as Russell states, would be that an observer on Venus could hardly see objects less than 50 miles in diameter and would have great difficulty in distinguishing permanent features because of varying clouds.

The Canals of Mars

The planet Mars has attracted more popular interest and has probably been observed more extensively than all the other planets combined. This is not surprising, for, although a small planet with one half the diameter and one tenth the mass of the earth, it comes nearer to the earth than any other large planet except Venus. It has an atmosphere, although not a dense one, and unlike Venus we can observe its surface directly and find there numerous conspicuous and in some respects unique markings.

The period of rotation, the Martian day, has been determined with great accuracy and is 24 hours and 37 minutes, so nearly like our own that features on

TWO VIEWS OF MARS

TAKEN ABOUT A MONTH APART AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY WITH THE 60-INCH TELESCOPE. THE DIAMETER OF MARS IS ABOUT ONE HALF THAT OF THE EARTH AND ITS MASS ABOUT ONE TENTH. IT HAS AN ATMOSPHERE, THOUGH NOT A DENSE ONE. ITS GENERAL SURFACE IS REDDISH WITH SHARPLY BOUNDED AREAS OF GRAY OR DULL GREEN. THE POLAR CAPS CHANGE CONSPICUOUSLY, BEING LARGEST IN THE MARTIAN WINTER AND SMALLEST IN SUMMER. SOME ASTRONOMERS THINK THAT A CERTAIN NETWORK OF FINE MARKINGS ON THE SURFACE OF MARS IS OF ARTIFICIAL ORIGIN, BUT THIS EXPLANATION IS NOT GENERALLY ACCEPTED.

the surface of the planet are seen in closely the same position by an observer on successive nights.

The color of the general surface of Mars is reddish, from which comes the name the ruddy planet, but nearly one half its surface is covered by darker areas of a gray or dull green color sharply bounded in many cases. At the poles of the planet are two brilliant white areas, the polar caps, which show conspicuous changes with the Martian seasons, being largest in winter and smallest in summer. The southern polar cap has been known to disappear completely toward the end of the summer season, but the northern always remains visible, although greatly diminished in size. It is difficult to conclude that these areas are not actually covered with snow or ice, although the rate of melting indicates that the deposit must be relatively thin.

Accompanying the melting of the polar caps are certain changes, which appear to be well established, in the color of the large dark areas toward the equator of the planet. The general tendency is for these areas to become darker and more prominent in the spring season for each hemisphere and to fade and become more yellow in the autumn of the year. Lowell and others have ascribed these changes to the presence of vegetation.

Associated with this effect is the vexed question of the canals on Mars, observed by Lowell as fine narrow straight markings making a network covering much of both the dark and the reddish areas of the planet. That fine details are present on the surface of Mars which could form a basis for Lowell's observations is beyond question, but the existence of markings which can hardly be interpreted as of other than artificial origin is subject to serious doubt in view of the results of other experienced observers.

PROOF OF ATMOSPHERE

The presence of an atmosphere around Mars has been proved in a variety of different ways. One of the most interesting of these is through such a

series of photographs in light of different colors as was first made by Dr. Wright of the Lick Observatory. The photograph in red light shows a great quantity of detail on the surface of the planet, while that in violet light shows almost none.

The red light can pierce through the haze of the planet's atmosphere, while the violet light has little penetrating power. Moreover, the size of the image in violet light is greater than that in red light, thus indicating that the atmosphere stops the violet light above the level of the surface and gives the appearance of a larger disk. Clouds have occasionally been observed in the atmosphere of Mars but are comparatively infrequent.

Spectroscopic investigations of the atmosphere have been made by many observers, notably at the Lick, Lowell and Mount Wilson observatories, mainly with a view to determining the amount of oxygen and water vapor.

Dr. Campbell's observations, made by him when at the Lick Observatory, proved definitely that the quantity of these gases in the atmosphere of Mars must be small, and later observations have abundantly confirmed his results. The most recent investigation undertaken with the powerful equipment at Mount Wilson indicates that the amount of free oxygen above a given area of the surface of Mars can not exceed one tenth of one per cent. of that above an equal area of the earth's surface at sea level.

While the presence of water vapor seems to be well established by the existence of the polar caps, the total amount of water contained in them need not exceed that in a large lake and could hardly be detected in the form of water vapor distributed throughout the planet's atmosphere.

Temperatures on Mars

Measurements of the temperatures of Mars have led to most interesting results. When Mars is nearest the sun the temperature of the surface exposed to the strongest solar radiation reaches about 60° Fahrenheit. When Mars is farthest from the sun this drops to about the freezing temperature. The polar caps may become extremely cold, more than 100° below zero Fahrenheit.

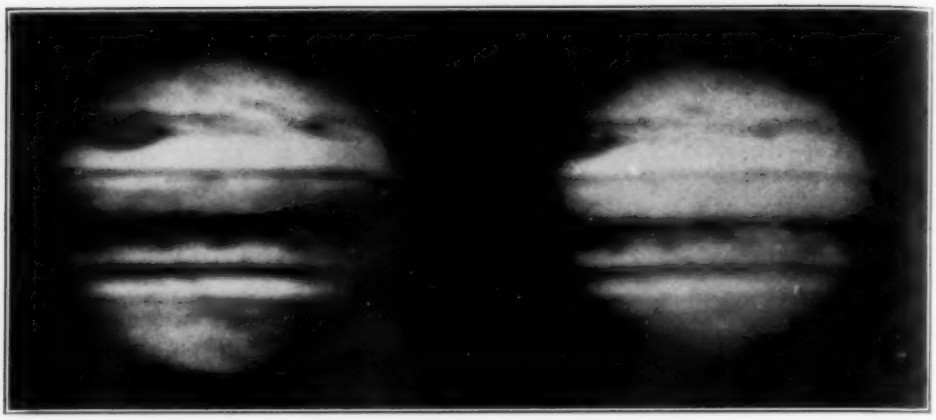
The important question of the temperature of the dark side of Mars is a very difficult one to answer because of the very small area which can be observed, even at the most favorable phase. The observations indicate that the temperature must be at least 40° below zero and perhaps considerably lower.

If we sum up conditions on Mars we find a small planet with little water vapor and very little oxygen whose sunlit surface in the tropics only at the most favorable times reaches temperate conditions and during much of the time is at a freezing temperature. Every 24 hours, as the planet rotates, the surface reaches a temperature of at least 40° below zero. It is clear from the observations that the atmosphere of Mars is of such low density that its shielding effect is small, and that the surface warms and cools with a rapidity far greater than that of any desert on the earth and only less than that of the moon itself.

Under such conditions if we can conceive of any vegetation on Mars it would seem that it must be of a rudimentary type which requires little nourishment from the atmosphere and gives out correspondingly little oxygen. The suggestion has been made that the free oxygen which may in past ages have formed a part of the atmosphere of the planet has been exhausted in the oxidation of the surface, and the general color of the surface is quite in keeping with this possibility.

The Asteroids

As we pass outward in the solar system beyond Mars we come to the zone of the asteroids, of which some 1,500 are known and many thousands doubtless



TWO VIEWS OF JUPITER

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY, THE ONE IN ULTRA-VIOLET LIGHT, THE OTHER IN BLUE-VIOLET LIGHT. JUPITER, ONE OF THE BRIGHTEST OBJECTS IN THE SKY, IS THE LARGEST PLANET, HAVING A DIAMETER ELEVEN TIMES THAT OF THE EARTH. THE MOST CONSPICUOUS FEATURES ARE THE BELTS WHICH EXHIBIT A GREAT VARIETY OF DETAIL AND COLOR AND WHICH OFTEN CHANGE RAPIDLY IN FORM. IT IS ALMOST CERTAIN THAT THESE ARE CLOUDS, PROBABLY NOT OF WATER BUT OF SOME SUBSTANCE THAT VAPORIZES AT A LOWER TEMPERATURE. JUPITER HAS NINE SATELLITES. FOUR OF THEM WERE DISCOVERED BY GALILEO IN 1610.

exist. They are small bodies, the largest less than 500 miles in diameter, moving in independent orbits around the sun and far too small to retain an atmosphere. Like the moon they must heat quickly on the side toward the sun and cool quickly as the sun's heat leaves their surface. The force of gravity is so low on the smallest of these asteroids that a hypothetical man could readily throw a stone from the surface into space and thus create an independent planet.

The Major Planets

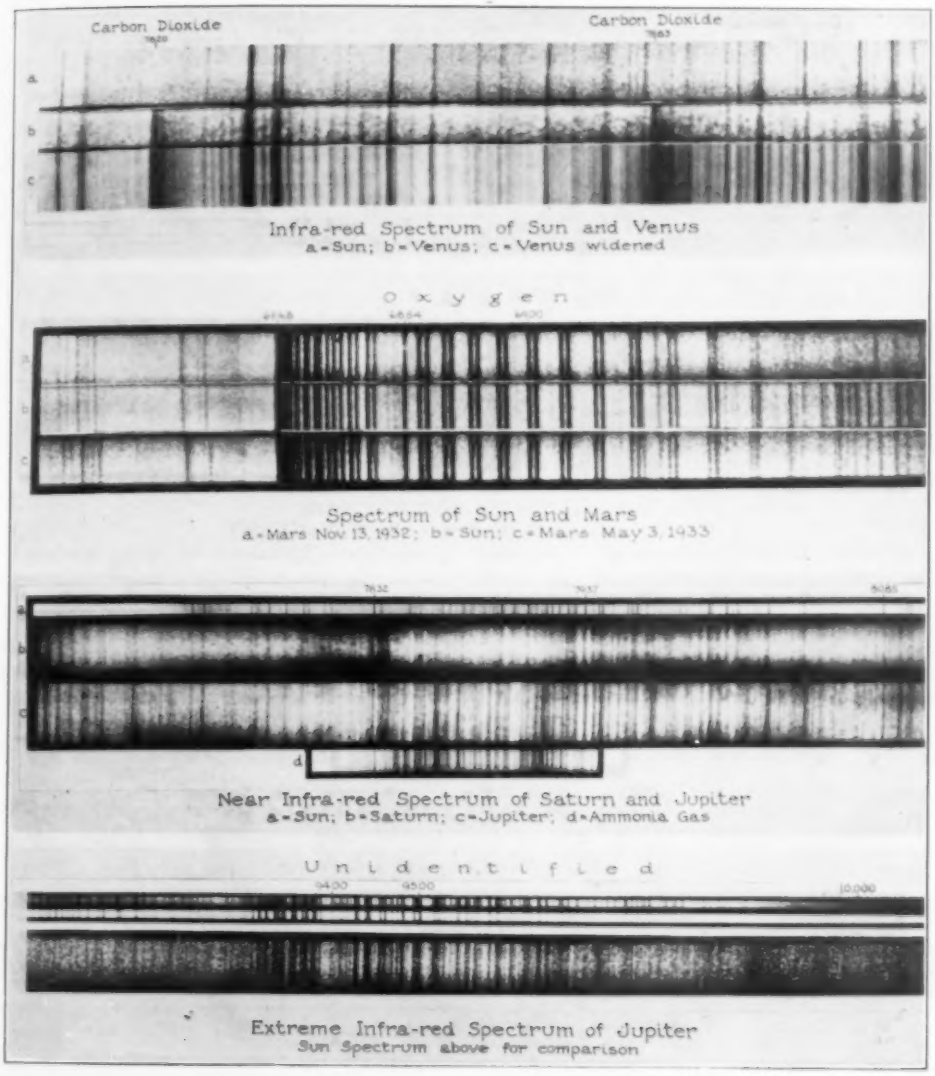
With the major planets Jupiter, Saturn, Uranus and Neptune we pass to an entirely different class of physical objects. They have large masses, rotate rapidly and are at such great distances from the sun that they receive very little heat.

Jupiter and Saturn have extensive systems of satellites, miniature solar systems in themselves. They have dense atmospheres of great depth which prevent us from seeing down to the surfaces of the planets, if such surfaces exist, and all their markings are subject to change, although in some cases they persist for long periods. Clearly they are atmospheric phenomena and may take place on an enormous scale. The great red spot on Jupiter, for example, was 30,000 miles long and 7,000 miles wide and lasted for many years, gradually becoming rounder and smaller until it has now almost disappeared. The white spot on Saturn discovered this year at the Naval Observatory was also very large and changed its form with great rapidity.

A remarkable fact about Jupiter and Saturn, and perhaps about Uranus and Neptune, as well, is that they do not rotate as solid bodies but more rapidly near the equator than in higher latitudes. The belted appearance of the planets, so striking in the case of Jupiter and Saturn, is probably associated with the character of their rotation.

Unknown Bands

The analysis of the light reaching us from these planets shows the presence of


Carbon Dioxide
Carbon Dioxide
a
b
c
Infra-red Spectrum of Sun and Venus
a-Sun; b-Venus; c-Venus widened
O x y g e n
Spectrum of Sun and Mars
a-Mars Nov 13, 1932; b-Sun; c-Mars May 3, 1933
d
Near Infra-red Spectrum of Saturn and Jupiter
a-Sun; b-Saturn; c-Jupiter; d-Ammonia Gas
U n i d e n t i f i e d
Extreme Infra-red Spectrum of Jupiter
Sun Spectrum above for comparison

SHOWING SPECTRA OF THE SUN AND PLANETS

TAKEN AT THE CARNEGIE INSTITUTION'S MOUNT WILSON OBSERVATORY. A GLOWING GAS OR VAPOR EMITS WAVES OF RADIATION, EACH HAVING A CHARACTERISTIC LENGTH. WHEN THESE ARE SORTED OUT BY THE SPECTROSCOPE AND THE SPECTRUM PHOTOGRAPHED, THE PRINT SHOWS A NUMBER OF LINES ON A CONTRASTING BACKGROUND. THE POSITION OF EACH LINE IN RELATION TO THE OTHER LINES IN THE SPECTRUM TELLS WHAT WAVE-LENGTHS PRODUCED IT. THE SPECTRA OF ELEMENTS DIFFER GREATLY; SOME CONTAIN BUT FEW LINES, OTHERS, THOUSANDS; BUT FROM WHATEVER SOURCE THE RADIATION IS DERIVED THE SPECTRUM OF A GIVEN ELEMENT IS ALWAYS THE SAME. IN THE SPECTROSCOPE, THEREFORE, THE ASTRONOMER HAS DEVELOPED A NEW TOOL AFFORDING ALMOST LIMITLESS POSSIBILITIES IN HIS STUDY OF THE NATURE OF THE PHYSICAL UNIVERSE.

numerous bands in the red and infra-red portions of the spectrum, some of which are very prominent, especially in the atmospheres of Uranus and Neptune.

The origin of most of these bands is still unknown, but recently Wildt and Dunham have identified several with bands produced by ammonia gas and methane. The bands due to ammonia are more prominent in the spectrum of Jupiter and those of methane in that of Saturn. Comparisons with laboratory results indicate that the ammonia present in the atmosphere of Jupiter is equivalent to a layer of gas 30 feet thick at atmospheric pressure. A minimum temperature of about 180° Fahrenheit below zero may be inferred from the observations.

It seems highly probable that the unknown bands in the spectra of the outer planets are also due to gases compounded of hydrogen and carbon, since hydrogen must be very abundant in their atmospheres.

The Rings of Saturn

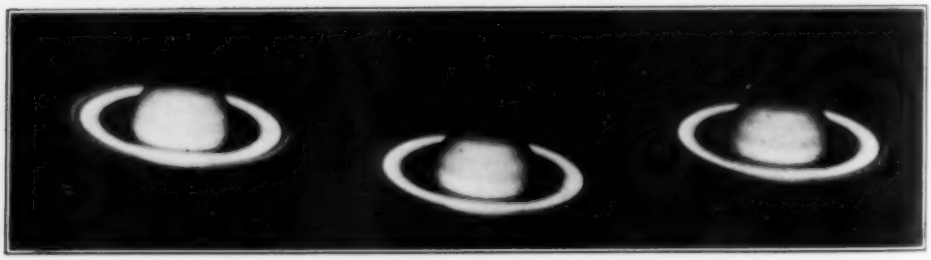
No description of the major planets is adequate without some reference to that unique feature of the solar system, the rings of Saturn. Although of extraordinary beauty and great mathematical interest, physically they are of less importance, since they possess no atmosphere.

It has been shown both by measurements of the reflected light and observations of the motions of different portions of the rings that they consist of a swarm of little satellites, each of which follows its own orbit about the planet. The thickness of the ring is extremely small, not more than 10 miles at most, and when its plane is turned toward the earth it is lost to sight for a few days, even in the most powerful telescopes.

Pluto, the Most Distant

The latest and most distant addition to the number of known planets is Pluto. Its mean distance from the sun is about 40 times that of the earth and its mass, the determination of which is subject to great uncertainty, is about one tenth that of the earth. Receiving but very little heat from the sun and plunged in the cold of space, this unexpected dwarf of the solar system is distinctly an object for sympathy.

Unlike the giant planets which are its nearest neighbors, Pluto is too small to have reserves in its own mass upon which to rely, and it has probably lost any atmosphere it may once have had, although some remnants of nearly inert gas may



THREE VIEWS OF SATURN

Taken at the Carnegie Institution's Mount Wilson Observatory with the 60-inch telescope. Saturn is unique in being encircled by three concentric rings which are composed of a swarm of little satellites, each of which pursues its own independent circular orbit around the planet, while moving in almost exactly the same plane. These rings, the outermost having a diameter of 171,000 miles, are extremely thin, probably not exceeding ten miles. Both Jupiter and Saturn have dense atmospheres which hide their surfaces, if surfaces actually exist.

still cling about it. Seen in the largest teleseopes as merely a faint star it is probable that we shall never gain any considerable knowledge of its physical constitution.

Doubtful if Life Exists

It is clear from this outline of some of the conclusions regarding physical conditions upon the planets that only two of them, Venus and Mars, can by any stretch of the imagination be regarded as possible abodes of life. Of these Venus must, so far as we can judge, remain largely a subject for speculation.

We can not see its surface or analyze its lower atmosphere, and although the absence of oxygen in its upper atmosphere and the apparently long period of rotation are unfavorable factors, it is quite impossible to state definitely that life may not have developed upon its surface.

With Mars the case against the existence of life appears much stronger. The surface of the planet can be studied directly and the atmosphere examined throughout its entire depth. It appears like a dying world with little or no oxygen and little water, subjected daily to great extremes of temperature as the sun rises and sets upon its surface.

Modern theories of the origin of the system of the planets indicate that the probability of the development of such systems among the myriads of stars is very much lower than we used to believe, and that they may be relatively few in number. Similarly, as our knowledge of the planets increases, we may be led to the conclusion that quite possibly the earth is the only planet which can at the present time support life, and so that in the universe as a whole life is a much rarer and more precious thing than we once realized.

A ZOOLOGIST IN THE PANTANAL OF THE UPPER PARAGUAY

By JAMES A. G. REHN

SECRETARY, ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

EVERY zoologist, and probably every botanist, critically studying any part of the Neotropical biota is confronted with numerous historic species described from "Brazil," without further exact locality. Probably no single large area of the world, except the classic "Indes orientales" of the older French workers, has been so frequently and indefinitely given as the habitat of this or that new discovery. The particularly exasperating angle of this indefiniteness is that in but a small percentage of cases can a modern student determine who originally secured the material, or even approximately where. Very frequently the type material has long since disappeared from collections. The many problems raised by modern intensive work can usually be solved in such cases by topotypic specimens, or individuals taken subsequently at the original locality, but this involves definite knowledge of the latter.

The vast extent of Brazil, reaching from 5° N to as far as 33° S, and with an area slightly larger than the United States, exclusive of Alaska or all Europe, as well as a diversity of surface conditions equaled by few other countries, is often unrealized even by otherwise well-informed people.

Virtually every student of the Neotropical biota is involved in the tantalizing indefiniteness of the early literature, as a true knowledge of the character and relationships of the life of southeastern Colombia, eastern Ecuador and Peru and northeastern Bolivia can not be secured without broad consideration of that of Amazonian Brazil, constituting as these areas do but parts of a single great cohesive biotic province, probably the richest in the world in the diversity of its life. The frequent use of "Brazil" as an original locality may thus constitute a taxonomically disconcerting factor when studying the life of any Amazonian area, even outside of the political boundaries of Brazil.

Roughly, the more outstanding biotic areas of Brazil are: (a) the relatively old mountain area to the north, separating that country from Venezuela and the Guianas; (b) humid, usually forested, Amazonia; (c) the ancient eastern and central plateaus and mountain groups which are often in large part semi-arid, as well as treeless "chapadão" over much of the western prolongation of this area in the Amazon-Paraguay divide; (d) the heavily forested belt of the coastal mountains of southeastern Brazil; (e) the relatively high and cool Paraná pine (*Araucaria*) district, in the same general region, and (f) the Paraguay River drainage of Matto Grosso, most of São Paulo and the western part of the other more southern states, which in the immediate vicinity of the Paraguay becomes a "pantanal" or seasonally flooded river plain of broad expanse. Many further subdivisions can be suggested by the student of Brazilian faunistics, but the major ones given will illustrate the fundamental diversity of the basic factors affecting animal and plant life in Brazil.

The Brazilian state of Matto Grosso lies in the south-central part of the country, in contact with Bolivia and Paraguay along its entire western boundary, and embraces within its limits a large

FIG. 1. OX-BOW CUT-OFF OF RIO PARAGUAY AT DESCALVADOS
SHOWING FLOATING MATS OF "CAMALOTES," A RELATIVE OF OUR WATER-HYACINTH, AND THE TANGLED, JUNGLY CHARACTER OF RIVERINE SCREEN FOREST. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

part of the Brazilian section of the Paraguay River drainage. The head streams of a number of the chief southern tributaries of the Amazon are similarly included. The plateau which forms so much of the Amazon-Paraguay divide, with its "chapadão," is also largely in Matto Grosso. The state has an area about twice that of Texas, or to be exact 532,683 square miles. Few elevations within its borders reach as much as 3,000 feet above the sea, but what is lacking in contour diversity is made up in other physiographic contrasts. To the northward we have Amazonian forests, particularly along the stream courses, passing into the "chapadão" and open forest country of the plateau divide, succeeded southward by the vast, nearly level, low river plain, elevated but slightly above the river, and during the rainy season, which extends from October to April, and for several months thereafter, is almost entirely flooded to a depth of from a few inches to as much as six feet. This country is the "pantanal" of the Brazilian, in general consisting when dry of open grassy campo-like plains dotted with usually circular islands of tangled forest, known as caapões (pronounced capõns), and with riverine screens of similar jungle forest. Many shallow channels, called "corixos" (corichos), filled with tall sedge and papyrus, wind through the pantanal or spread out in broad sloughs. During the dry season rain may not fall for as much as three and a half months, the campo grass-land bakes dry, the grass sun-cures, the corixos largely dry up, being merely water pockets and not flowing stream courses, and many of the caapões trees become leafless. The native Borero Indian cattlemen then burn off the dry grass, and the smoke of grass fires is much in evidence. While the

temperature may at times be high, the dry season is "winter" in the pantanal, and cold south winds, the backwash of Argentine "pamperos," blow for days at a stretch; the writer has seen the temperature drop from 97° to 40° F. in ten hours.

To the systematist who has worked on the fauna of Matto Grosso the name of one field collector of the past is particularly familiar. Probably his labors placed in the hands of students as great a variety of material from several localities in South America as any one of this group of scientific pioneers. It is pleasing to know that Herbert H. Smith was an American, and that virtually all his vast Brazilian collections are housed in American institutions. In the breadth of his work and its scientific results, his Brazilian efforts place his name in that coterie of zoological trail-breakers in Brazil which includes Spix, Natterer, Bates and Wallace. Of these Natterer was the only other one who touched the state of Matto Grosso, the northern portion of which he crossed on his way to the Rio Madeira, a trail of many perils then and hardly a pleasure stroll to-day.

Smith's work in Matto Grosso was done at two localities: first, the vicinity of the old city of Corumbá on the Rio Paraguay, bordered on the north and east by low pantanal, with the elevated square-cut massif of Urucúm on the south; and second, the town of Santa Anna de Chapada, twenty or more miles northeast of Cuyabá, capital of the state, situated on the Paraguay-Amazon divide and near the characteristic "chapadão" of that area. At these two localities, but especially at Chapada, Smith and the other members of his party collected intensively for several years, and amassed really amazing collections of mammals, birds, reptiles, fishes, insects and other animals, which served as the base for classic studies by Cope, J. A. Allen, Cal-

FIG. 2. DESCALVADOS FROM THE AIR

SHOWING THE SINUOUS COURSE OF THE RIO PARAGUAY, AND THE DIVERSIFIED COVER CONDITIONS OF THE PANTANAL. DESCALVADOS IS THE LARGEST SETTLEMENT ALONG SOME THREE HUNDRED MILES OF THE PARAGUAY BETWEEN CORUMBÁ AND SÃO LUIZ DE CAÇERES. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 3. PANTANAL CONDITIONS IN APRIL AND MAY

THE LATTER PART OF THE WET SEASON. THE TERMITES' NESTS ARE SOMETIMES UNDERCUT BY THE WATER AND TOPPLE OVER. THE WHITE BIRDS IN THE DISTANT SLOUGH ARE LARGELY WOOD IBIS, WHICH FIND THESE AREAS PRODUCTIVE FEEDING GROUNDS. WHEN THE SAME COUNTRY WAS LARGELY DRY, WATER BIRDS WERE MUCH LESS IN EVIDENCE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

vert and many others. Considerable portions of these vast collections are yet unreported, while studies on other sections are being made by a number of specialists. My personal interest in Matto Grosso zoology came through work years ago on a portion of Smith's series of Orthoptera.

In 1930 an expedition was organized in the United States, having as two of its objects the securing of motion pictures of the wild life, human and animal, of parts of Matto Grosso, and the examination of little-known country on the upper Rio Xingú, one of the main southern tributaries of the Amazon. It was known as the Matto Grosso Expedition, and had attached to it as anthropologist and archeologist Mr. Vincent M. Petrullo, of the University Museum of Philadelphia, and subsequently the writer was added to the expedition as zoologist, representing the Academy of Natural Sciences of Philadelphia.

Mr. Petrullo's splendid work among the little known peoples of the upper Rio Xingú (pronounced Shin-gú) has been ably described by him in the publications of the University Museum.[1]

The personnel of the Matto Grosso Expedition other than native help comprised eighteen persons, all but four of whom were American. The main party left New York in December, 1930, and

[1] *Museum Journal*, xxiii: No. 2, 91–173, pls. xix–xxiv, map, 1932.

the last members of the expedition returned to the United States about a year later. In order to insure the best possible success in jaguar hunting, a number of hounds trained on puma in the United States were taken. The value of these dogs over the average native one for trailing was beyond question, in spite of declarations by some that imported hounds would not be as useful as native dogs. The expedition was the fortunate possessor of its own short-wave radio equipment and for about five months had the use of an amphibian plane and crew of three. This was of exceptional value in connection with the anthropological reconnaissance of the upper Rio Xingú.

In order to permit the best hunting, the stay of the expedition was planned to cover the entire dry season, when the pantanal country, where the largest type of jaguar known occurs, is driest and trailing has the best chance of success. For other groups of animals than mammals, however, with the possible exception of birds, the dry or winter season, with its very cool spells and its lack of rain was, as in the American tropics as a whole, distinctly less productive than the wet season. While the latter season is the one more trying to the field worker, it is in many ways more productive in results. For anthropological work, with its relative ease of land travel, and for aerial reconnaissance, the dry season is distinctly the better.

FIG. 4. JAGUAR AND PUMA FROM THE PANTANAL

THE LARGE MALE JAGUAR IN THE CENTER WEIGHED 290 POUNDS SOME HOURS AFTER DEATH. THE HEAVY BUILD AND POWERFUL FORELIMBS OF THE JAGUAR ARE HERE WELL CONTRASTED WITH THOSE OF THE MORE SLENDER PUMA. THE KILLING POWER OF THESE MAKES THE JAGUAR A FAR MORE SERIOUS PROBLEM TO THE CATTLEMAN. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

The base of the Matto Grosso Expedition was established at Descalvados, on the upper Rio Paraguay, the station of the Brazil Land and Cattle Company, well over two hundred and fifty miles by stream and about one hundred and seventy-five in an air-line due north of Corumbá. Descalvados is a "xarqui" (pronounced char-kee), or jerked beef, slaughtering and drying plant, and under its now deceased manager, John Gordon Ramsey, it has served in the past two decades as a base for several zoological expeditions, while the Roosevelt-Rondon Expedition visited it on the way to Tapiropoan and on over the chapadão to the descent of the Rio Roosevelt. Ramsey, a former Texas sheriff and cattleman, will always remain an unforgettable figure in the memory of those fortunate enough to have had the friendship of this courageous and generous exemplar of the best in our pioneer days. At Descalvados, under conditions entirely different from those of our West, he had developed in the Borero Indian cattlemen an unusual loyalty on account of his fairness, coupled with the application to the guilty of the justice of our old frontier. In a land where life is still held lightly, he was to the evil-doer a living personification of the maxim that the way of the transgressor is hard.

The Boreros of Descalvados represent a sadly decultured branch of that distinctive people, and have been in contact with white men for many decades, as the upper Paraguay served as part of the route of the Spanish conquistadores on the long trail from Asuncion to Lima, a hard journey to-day and an almost unbelievably arduous one in the sixteenth and seventeenth centuries. The Descalvados Boreros in the past decades have acquired a pronounced Negro admixture, adopted the white man's clothes and largely speak Portuguese, as well as their own tongue. On the Rio São Lourenco, an important eastern tributary of the upper Rio Paraguay, about two hundred miles southeast from Descalvados, one of the branches of the Borero people lives in essentially their primitive condition, having been hostile to whites until a few decades past. Through the cooperation of General Candido Mariano da Silva Rondon, the distinguished Brazilian administrator and explorer, whose interest in the welfare of the aborigines of his country is sincere and understanding, members of our expedition were permitted to visit these interesting people and secure motion pictures and sound records of their dances, songs and mode of life. Brazil, it is pleasing to know, has adopted a policy of protecting its still considerable Indian population from exploitation and pseudo-scientific "racketeering," yet providing for genuine scientific recording and preservation of anthropological and ethnological information before inevitable changing conditions make this impossible.

The scientific members of the Matto Grosso Expedition look back with pleasure on the uniformly cordial cooperation and invaluable assistance received from the Brazilian Government and all its officials with whom they came in contact. No more generous consideration has been extended to the writer in field work involving seven different Latin-American countries. The cooperation of Brazilian scientists was equally generous and helpful, fully in keeping with the extreme cordiality which has marked Brazilian-American relations of all character.

FIG. 5. RED OR MANED WOLF (*CHRYSOCYON BRACHYURUS*)
ONE OF THE MOST STRIKING AND DISTINCTIVE ANIMALS OF THE RIO PARAGUAY BASIN.

The Rio Paraguay at Descalvados, where the writer spent the four months between May and October, occupied with hunting and zoological collecting, is a stream about two to three hundred yards wide, swift and powerful in spite of its low elevation (approximately six hundred feet) there, about two thousand miles from the sea. The river has many holes, some being over forty feet deep at low stages of the water, although toward the end of the dry season shoals often give trouble to the shallow draught river steamer, which operates between Corumbá and the town of São Luiz de Caçeres, some seventy miles upstream from Descalvados. Caçeres is an old settlement and has figured conspicuously in the past history, and the natural history, of Matto Grosso. In the past it was also called Villa Maria, and is so quoted in some of the older scientific literature.

Some fifty miles or so down stream from Descalvados the Paraguay breaks up into several channels which squirm and twist through forest-bordered pan-

tanal. The navigation of these tortuous waterways requires skill and experience at the helm of the steamer, particularly with freight barges lashed on the sides, as is the usual custom.

A hundred or more miles above Corumbá the various channels merge into a deep powerful stream, which flows among the eastern ridges of a rugged mountainous area. This uplift, rising out of the pantanal and the ghostly lakes of Uberaba, Guiba and Mandioré, stretches far off westward into Bolivia. The July airplane panorama of these apparently ancient mountains, rising from the flooded pantanal and reaching off toward the setting sun, range beyond range, deep into Bolivia, is something not readily forgotten. Their dry slopes show many candelabra cacti (*Cereus peruvianus*), which are locally called urumbéva in Brazil, and are sometimes as tall as forty-five feet, while the hill slopes are also dotted with the pink and yellow flowers of the peúvas. We know little of these mountains or their animal life. They have never been accurately surveyed and are charted on the best Brazilian maps as just surpassing three hundred meters in elevation. With our plane we cleared the summit of one of the higher peaks by about two hundred feet and found its height was approximately four thousand feet above the level of the Rio Paraguay.

FIG. 7. TREE PORCUPINE (*COENDU*)
(PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 6. THE LARGE OTTER OR "ARE-INHA" (*LUTRA BRASILIENSIS*)
THE FLATTENED TAIL IS EVIDENT IN THE PHOTOGRAPH. THE FRINGED LEATHER APRON OF THE BORERÓ CATTLEMAN IS SEEN ON THE FIGURE TO THE LEFT.

To return to the Paraguay at Descalvados, the surface of the river generally bears floating islands or marginal fringes of "camalotes" (*Eichhornia* and *Pontederia*), larger cousins of the water-hyacinth of our southern states. These mats of vegetation often solidly choke the channels of ox-bow cut-offs which lead back from the main stream. Quiet shallow pools or small lagoons with little or no current will shelter the glorious "rainha dos lagos" or queen of the lakes, a species closely related to the *Victoria regia* of more northern South America.

The dense fringe of jungly forest which borders the river, and for long distances forms a screen cutting off the hinterland, is made up of a large number of species of trees. This forest, being more generally inundated during high water than the drier caapões, has a different fascies. It is what might be called more truly tropical in the more frequent palms, of which the carandá palm (*Copernicia cerifera*) is the most abundant, while others are the "auassú" (*Orbignia speciosa*), the burity palm (*Mauritia*) and the great-leaved "acury" (*Attalea*), a near relative of the Central American corozo or manaca palm. Among the many other riverine forest

components may be mentioned great wild figs or "figueiras" (*Ficus*), species of *Cercopia*, locally called "umbaubeira," which is the "guarumo" or trumpet tree of much of Spanish America, the false dragon's blood (*Heliocarpus americanus*) and the "pão santo" (*Bulnesia sarmienti*). The fringe forest is often almost solidly mantled with a blanket of vines, tying all into mounds or domes of green, as seen from the stream. When the water is high all the land bearing the riverine forest is inundated or at least but a few inches above the flood.

The open pantanal of campo character is generally treeless, short-grassed, level, sometimes with an open grove-like tree cover of species of relatively low stature, most of which become completely leafless by the end of the dry season. The dense caapões are scattered like islands over the campo and wetter pantanal, usually elevated a few feet above the general level and thus generally dry most of the year, serving as refuges for many mammals during the flood time. They are generally circular in outline, which is particularly pronounced when the pantanal is seen from a plane, and rise quite sharply from the campo, with no definite transition area. The densely matted tree growth is made up of many kinds, most conspicuous of which are the great-leaved "lixeira" (*Curatella americana*), species of wild fig (*Ficus*), several palms, the giant jatobá (*Hymenaea*), species of *Inga*, called "ingasinho," and lianes of varied and strange type, of which the "cipó de escada" (probably a *Bauhinia*), with its ladder-like convolutions, draws prompt attention. On the few low, rocky hills near Descalvados —apparently isolated remnants of the mountains to the south already mentioned—one finds a more xerophytic vegetation, with candelabra cactus, low spiny agave-like types and the yellow and red flowered peúva trees, locally "peúva amarella" (*Tecoma ochracea*) and "peúva roxa" (*T. ipe*). These beautiful trees in the dry season are mantled with great clusters of golden yellow and purplish pink trumpet-like blooms, although then quite leafless. The wet swales of the pantanal, with their standing water, are densely grown

FIG. 8. FALSE VAMPIRE BAT (*VAMPYRUM SPECTRUM*)

THIS SPECIMEN MEASURED THIRTY INCHES ACROSS THE FULLY EXTENDED WINGS. IT KILLED AND DEVOURED A SMALLER BAT WHICH WAS PLACED IN A CAGE WITH IT. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

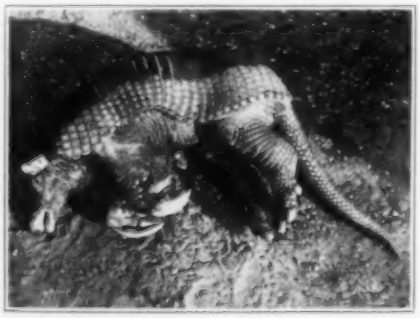


FIG. 9. GIANT ARMADILLO (*PRIODONTES GIGANTEUS*)

THIS SPECIMEN, THE FIRST OF THREE CAPTURED ALIVE, DIED IN TRANSIT THE NIGHT BEFORE REACHING OUR HEADQUARTERS. THE GREAT DIGGING CLAWS ARE USED BY THE PRIMITIVE BORERÓS IN ONE OF THEIR DISTINCTIVE NECK PENDANTS. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 10. WATER BIRD LIFE ON THE PANTANAL AT THE END OF THE WET SEASON

THESE ARE MAINLY EGRETS AND WOOD IBIS. THE STANDING LARGE BIRDS WITH BLACK NECKS ARE JABIRÚS. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

up in a tall coarse sedge, which has much the same cutting propensities as Florida saw-grass. Often these areas occupy many acres, filling every slight depression in the land. In the deepest wet spots are dense eight-foot stands of papyrus. Many shallow lagoons are scattered over the pantanal, bearing great mats of "camalotes" and the "rainha dos lagos" much as embayments of the more truly riverine sections. Until the middle of the dry season the recurrent splashing of water, when crossing the corixos or shallow pools, is the regular accompaniment of pantanal travel in the saddle. This brief picture of the major features of pantanal landscape will give a background for comments on its more evident animal life.

Any mention of the great cats at once brings forward the African lion as the standard of comparison. In reality he is unique among the larger cats in a number of respects and correspondingly non-representative. None of the other large felids are as gregarious as the lion is often found to be, and they are as a whole more forest-loving. One will not find the various forms of jaguars or pumas congregating in fair-sized groups, and their siestas are by preference taken in heavy cover. Consequently, they are far less evident features of the landscape than lions are in Africa. The species or subspecies of the jaguar of the pantanal region (*Felis onca milleri*) is the largest form of this greatest of New World cats. The relationships of the various forms of jaguars have been the subject of recent investigation by Messrs. Nelson and Goldman, and the technical name here used was recently proposed by them for the pantanal subspecies.

It is a common thing, even among otherwise well-informed people, to look upon the jaguar as merely an American counterpart of the leopard. In reality they have no resemblance in habits, much less in size and build. The jaguar is a far heavier animal, with more robust limbs, lower set and thicker body, shorter, heavier tail and more powerful head and neck. No Old World cat has proportionately as heavy fore limbs as the jaguar. The Matto Grosso Expedition secured fifteen jaguars, of which the largest weighed 290 pounds, a number of hours after death. This cat in life undoubtedly would have scaled 300 pounds, or equal in weight to a small African lion. The relative size of this huge male, as compared with a fair-sized female jaguar and an average puma, is shown in Fig. 4.

When cattle are not available or not particularly sought, the pantanal jaguar preys upon tapir, deer, capybara, rheas and even the alligator-like jacarés or caimans. It has even been known to

attack the great ant-eater, with fatal results to both, and doubtless will eat armadillos and various of the larger birds. Although he is an almost omnivorous feeder, tapir and capybara seem to be particularly liked. The hides of tapir often show deep claw marks where jaguars have attacked and been swept off by the tapir's headlong rush through dense brush, usually for the relative security of deep water. Nevertheless, the jaguar swims well and crosses large or swift bodies of water without difficulty. During the inundation of the wet season jacarés become more widely spread over the vast extent of the pantanal. As the flood sheet recedes these unprepossessing saurians are encountered wandering over dry land considerable distances from any water. In hunting one often finds the mummified remains of jacarés, always on their backs with the lower surface torn away, showing where some hungry jaguar stalked and slew.

The jaguar's hunting is generally done at night, while the day is usually spent in the depth of some dense caapõe. To these places the cats generally retire in the early morning, often taking a preliminary roll in a bed of grass or sedge. These beds are easily recognized. The sleeping place may at times be some distance from the "kill," if one has been made, or the cat will sleep near the kill, feeding again later. The position of the kill is generally evident from the attendant group of black vultures or "urubús." Apparently long distances are covered by jaguars in search of food, and in hunting them with hounds cold trails are sometimes followed for many miles before the spoor becomes fresh enough for the younger, "hot-trail" dogs. In one case we followed a trail for twelve miles before the cat came to bay.

Naturally cattlemen are deeply interested in the spotted killer, which takes a considerable toll of calves, cows and

FIG. 11. WOOD IBIS FLYING OVER FLOODED PANTANAL

THE SHRUB IN THE FOREGROUND IS KNOWN LOCALLY AS "CANUDO" OR "ALGODÃO DO PANTANAL" (WILD COTTON) (*Ipomoea fistulosa*) AND OCCUPIES A DEFINITE BELT IN THE DESCALVADOS PANTANAL. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

FIG. 12. JAWS OF THE WOLF FISH (*RHAMPHIODON*)
ONE OF THE HIGHLY SPECIALIZED MEMBERS OF THE GREAT FAMILY CHARACINIDAE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

steers, while much more rarely a bull, taken off guard, may be attacked. Native hunters kill a considerable number for their hides, the ranchers sometimes systematically endeavor to wipe out a particularly persistent cattle killer, yet jaguars remain in considerable numbers, unseen and usually unheard.

Pumas (*Felis concolor osgoodi*) are probably less numerous than jaguars in the pantanal, seem more partial to the drier areas and, being smaller, play a less important part. Occasionally a family group of as many as three will be encountered. Such a trio one day furnished us with two study specimens and a live individual. When closely pressed by hounds, they invariably tree, while jaguars may elect to bay on the ground, as I saw them do on two occasions. In dense growth a large jaguar at bay on the ground is a serious opponent for man or dog, as visibility may extend but a few yards, and a charging jaguar has speed all out of proportion to his build. The wise dog gives plenty of room, the careful hunter takes no chance of merely wounding the jaguar by a hasty shot. As elsewhere, pumas are less likely to attack cattle, and probably proportionately kill more deer and smaller mammals than do jaguars. The range of body color in the puma at Descalvados was from a rather dark grayish brown to a decidedly red brown tone.

The ocelot or "jaguaterica" (*Felis pardalis brasiliensis*) is probably the most persistent hunter of the smaller mammal and birds of the pantanal. It is at least partly diurnal in its hunting, as trails picked up any time in the day were fresh and soon led to this most beautiful of the smaller cats, which climbs with the greatest facility.

We did not encounter the interesting dichromatic yaguarundi cat (*Felis yagouaroundi*) or the very rare bush cat (*Felis pajeros braccatus*), which latter was described by Cope from H. H. Smith's collection and still remains one of the scarcest cats in scientific collections. Both species are known to occur in the pantanal.

The common wild dog of the Rio Paraguay campo is one of the forms of the crab-eating dog or "lobito," which is widely distributed over much of Brazil and adjacent countries to the south and southwest. It is a short-legged, dark, fox-like dog, which runs with great speed. The most unusual of the wild dogs of this portion of South America and one of the most distinctive in the world is the red or maned wolf (*Chrysocyon brachyurus*), the "lobo vermelho" of the Brazilians. This long-legged, great-eared animal suggests a gigantic, stilt-legged, short-tailed edition of the red fox. The very slender legs are black, as is the muzzle, while the general body color is a fox red. The hair along the back is rather long, suggesting a mane, and the short, poorly brushed tail gives an impression that the job of constructing a very striking animal was left unfinished. An interesting parallelism is that the marked coloration of this species and that of the large swamp

deer, living in the same territory, are very similar. However, this strange dog apparently feeds on small mammals and to some extent on wild fruit, such as the small figs of the figueiras. The experience of our party with the single one collected shows that the red wolf is a savage fighter when brought to bay, fully able to hold its own against hounds.

Two species of otter occur in the Rio Paraguay at Descalvados, the smaller (*Lutra paranensis*), called "lontra," the larger (*L. brasiliensis*), the "areinha." The latter species has been considered to be generically distinct, as it has the tail distinctly flattened, with a ridge on each side. It is one of the largest otters known, and in total length is sometimes but little short of six feet. This giant species, which ranges through much of South America to the Rio de la Plata, will sometimes be found in the Rio Paraguay in small family groups, engaged in the graceful gambols for which otters are noted.

The Procyonidae is represented by the red coati (*Nasua nasua solitaris*) and the crab-eating raccoon (*Procyon cancrivorus nigripes*). The former is more likely to be encountered in the forest areas, while the raccoon is probably more partial to the truly riverine section. Both are often tamed and make interesting pets. Dogs find the coati a formidable opponent on account of its triangular canines, which are capable of serious injury to a dog as large as a foxhound, as one of our animals learned.

A black species of howling monkey (*Allouatta caraya*) and a capuchin (*Cebus azarae*) are frequent in the forested areas, particularly along the river. The howlers, which show sex-correlated dichromatism, are often heard at night, or even on gray days. The members of the expedition made a brave effort to rear several half-grown howlers, but with the failure usually encountered in such attempts with these delicate monkeys. They were thoroughly tame and most likable and interesting pets, with their quiet, dignified manners and solemn mien, so in contrast to the rowdy capuchins in our menagerie. The howlers were never mischievous and could be allowed to roam free, returning at night, from their diurnal wanderings over paling fences and compound trees, to the comfort of their open cage. They soon made friends, and would confide their face-wrinkling worries in low but deep and throaty complaints. The slower action of the howlers was always evident when they came within reach of the chained capuchins, and a rough-and-tumble immediately developed.

The tapir (*Tapirus terrestris*) is usually considered to prefer the general neighborhood of water, and will often spend part of his time in it, while in such situations water plants form at least part of his food. In the Descalvados area, however, tapirs are some-

FIG. 13. JABIRUS (*JABIRU MYCTERIA*) ON NEST

THIS NEST WAS LOCATED IN THE RIVERINE FOREST AND A SERIES OF MOTION PICTURES OF THESE BIRDS WAS TAKEN FROM A VANTAGE POINT IN ANOTHER TREE. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

times met considerable distances from permanent water, feeding on wild fruit. An adult female secured by the expedition in the riverine forest weighed 459 pounds. While the Brazilian tapir is undoubtedly an ancient type, it has retained its specific characters unchanged over a considerable territory, as it ranges from Colombia and the Guianas to southern Brazil, Paraguay and northern Argentina. Why this species, or a near relative of it, should occur in the North American Pleistocene, and not the Central American genus *Tapirella*, where *Tapirus* does not occur, is not known, but is one of the many instances in which the differentiation of the life of Central America from that of the continents to the north and south of it is marked.

Of the deer of the pantanal the most conspicuous are the "veado" or pampas deer (*Blastocerus bezoarticus campestris*) and the "ciervo" or swamp deer (*Blastocerus dichotomus*). The first of these is distinctly smaller than our eastern Virginia deer, the buck with light, graceful antlers, and both sexes capable of speed and agility which suggests a jack rabbit, with the "sky hop" of the latter, probably for better observation. It is abundant and partial to the open grassy or park-like campo, while the "ciervo" is more truly a species of the wet pantanal. In size the latter is large and heavy bodied, equalling a large mule deer, in the male with symmetrical, well-spread antlers of the *Odocoileus* type, while the striking body color has been mentioned under the red wolf. In contrast with the active little veado, the ciervo is slow and confiding. Only when thoroughly frightened does it seem to realize that another neighborhood may be safer. In consequence, it is killed in numbers for its hide, which, however, brings but a pittance. Apparently this beautiful species will soon disappear from lands where it is to-day the largest deer and one of the most beautiful members of its family.

Both types of peccaries are encoun-

FIG. 14. JACARES (*CAIMAN*) ON THE BANK OF THE RIO PARAGUAY
THIS PICTURE ALSO GIVES AN IDEA OF THE DENSITY OF THE RIVERINE FRINGE FOREST. (PHOTOGRAPH BY MATTO GROSSO EXPEDITION.)

tered in the Descalvados area, the larger white-lipped species or "teschado" occurring in herds of up to a hundred or more, while the smaller collared species is usually in groups of from three to a dozen or so. The larger white-lipped peccary is always treated with caution, as it is a truculent pig, prone to charge if pressed too closely and capable of seriously injuring the hunter. Native dogs respect it and Indian hunters are careful in approaching the fortunately infrequent larger herds. The smaller collared species when pursued often takes refuge under partially uprooted trees or in similar places. When running for cover it can make surprising speed, bouncing along in a rabbit-like bolt. At bay, if pressed too closely, it can use its triangular canines with deadly effect, as many dogs have discovered. The collared peccary is more frequently seen than the white-lipped peccary, and is closely related to the forms found in Texas, New Mexico and Arizona.

Of the numerous rodents the capybara (*Hydrochoerus capybara*) is the most evident and interesting. This largest of the gnawing animals seldom wanders far from permanent water and is frequently found in groups, peacefully feeding or taking a sun-bath, close to the relative haven of the river or a corixo. The jaguar seems fond of capybara, while jacarés probably account for a number, but the modern demand for hides is apparently a greater factor in steadily reducing the number of these quaint and highly specialized rodents. Few of these are as truly water-loving as the capybara, which, with his truncate muzzle, small eyes and ears, deep body and pig-like bristles, seems to have been constructed of odds and ends. Agoutis (*Dasyprocta*), those slender-legged and active relatives of the guinea-pigs, were occasionally located by the dogs, but seldom seen otherwise, as they are chiefly nocturnal and exceedingly swift in their movements as they dash for safer cover. The tree porcupine (*Coendou*), the tropical American counterpart of our Canada porcupine, is infrequently encountered in the forest areas along the river, its prehensile tail added evidence that this feature has been a survival factor in many of the Neotropical mammalia.

Of the bats of the Rio Paraguay one proved of particular interest. The great false vampire (*Vampyrum spectrum*), the largest American bat, has a wing spread of over two feet. It apparently is not a common species and is also relatively rare in collections, although it has been known since before the days of Linnaeus. For many years it was considered to be a blood-sucker, and its technical name was given under this misapprehension. The true vampires belong to the distinct family Desmodontidae, and are much smaller species with highly specialized lancet-like incisor teeth. While several forms of the false vampire are now recognized, the species ranges from southern Mexico to Brazil. Nothing definite appears in the literature regarding the habits or food of this species. From my first acquaintance with museum specimens of the species its strongly developed canines always seemed out of place in a bat of frugivorous habits, such as those of many of its phyllostomatine relatives. A live specimen of this bat, which spread thirty inches across the wings, was captured by our party and placed in a cage. After it had eaten some finely cut beef, a smaller bat was placed with it. The false vampire promptly seized the smaller bat and, holding it with its wings, proceeded to devour it. Further experiments with *Vampyrum* were prevented by the death of the bat. Carnivorous habits have recently been reported as occurring in the related genus *Phyllostomus*, and the observations of our party show that at least two genera of

American bats share such habits with the Old World genus *Megaderma*. While the work of the true vampires was occasionally evident on our horses, no specimens of them were seen or taken.

No living edentates are more interesting and peculiar than the armadillos, of which three species, representing as many genera, were found by our party. The most outstanding of these, as well as the rarest, is the giant armadillo (*Priodontes giganteus*), or "tatu canestra." This, the largest of all living armadillos, measures as much as four feet, nine inches from nose to tip of tail, of which the powerful, tapering tail occupies over twenty inches. The largest digging claws of the front limbs are more than four inches in length. Its very large tunnel-like burrows are occasionally seen, but the animal is considered rare by all the native hunters. We managed to secure three, two alive, hoping to bring them to the United States in that condition, which I believe has never been done. Unfortunately, one escaped and the other, after feeding satisfactorily for a month, refused food and starved itself to death. One of these captives gave us an excellent illustration of the speed with which this most powerful of all American digging animals can bury itself out of sight. When but a few feet in its tunnel, the efforts of several men pulling on its tail were not sufficient to dislodge it or even seriously slow up its excavation work. This glyptodont-like genus is known to range from north central Argentina northward across eastern Bolivia and adjacent south central Brazil. Any promising young mammalogist, who wishes a unique experience in the preparation of material, should skin and skeletonize a giant armadillo. He will learn that for the size it can supply an unbelievable amount of hard work and tax his resourcefulness to an unequalled degree. The primitive Borero Indians prize the largest digging claws, which are used in pairs to make one of their most distinctive types of neck pendants.

Two ant-eaters are regularly encountered in the Descalvados area, the great ant-eater or ant-bear (*Myrmecophaga tridactyla*), the tamandua bandeira of the Brazilians, and the smaller tamandua ant-eater (*Tamandua chapadensis*). The former, with its strange build, very elongate head and broad brush-like tail, is not rare in the pantanal, living largely on termites, the hills of which it is able to open with its powerful fore claws. When frightened it lopes away with a peculiar rocking-horse gait, its great bushy tail going high with each drop of the fore quarters. Jaguars occasionally kill the great ant-eater, but the latter can defend itself most valiantly. Settling back on its hind quarters it delivers slashing blows with its fore limbs, which are armed with four-inch claws that cut like scythes. Probably only a jaguar hard pressed by hunger takes such risks, as these combats have been known to end fatally for the cat as well as the ant-eater.

The smaller tamandua is arboreal, its prehensile tail making it quite at home in that habitat. It is not uncommon and was brought to us alive by natives a number of times. One half-grown one became a most likable pet, with complete freedom of all our quarters, but radio battery acid proved too much for its innocently inquiring tongue. It fed most contentedly on the termites in chunks of their structures which were demolished for the purpose. Assiduously the pieces were gone over, and few termites escaped attention. This peaceful animal was never known to make a sound, until one day a captive young crab-eating dog nipped it; then our placid pet reared on its haunches, and with several lightning-like slashes drove the dog away, while in a high-pitched squealing voice it bid defiance to its assailant.

One of my unforgettable memories is

of the water birds on the Rio Paraguay at the end of the wet season. For variety and abundance they far surpassed anything I had previously experienced. Later in the dry season, when the completion of other work enabled me to turn my attention more to water birds, the abundance and variety was by no means so great. The local explanation is that the birds follow the receding water down the Paraguay. How true this is I do not know, but the abundance of early June was greatly depleted by early September.

The vast flocks were made up of many species, chief of which were wood ibis (*Mycteria americana*), egrets, group of roseate spoonbills (*Ajaja ajaja*), crying ibis (*Molydophanes caerulescens*), and most conspicuous and noteworthy of all the jabirú (*Jabiru mycteria*) or "tuyuyu" of the Boreros. This, the largest of American storks, stands as much as four feet high, snow white with the bare skin of the neck and head black, except for a collar of red or pink at its base, this color covering a gular pouch capable of marked inflation, particularly on the sides of the neck. The crown of the head bears a thin tuft of white hair-like feathers, which at close quarters adds to the ancient and dignified appearance of the bird. The bill of the jabirú curves up slightly in the end half. The jabirú nests in tall trees in the caapões or in an occasionally isolated one in the campo, constructing a huge structure, which is apparently added to year after year. Occasionally the community nesting "catita" parrots (*Myiopsitta monachus cotorra*) use the lower part of the jabirú's nest for one of their colonies. The young jabirú number two, and were still in the nest in August, solicitously tended by their devoted parents, although they were of quite fair size.

Wood ibis (*Mycteria americana*) were in very great numbers, as late as September often feeding by dozens in wet spots in the pantanal. The great cocoi heron (*Ardea cocoi*) frequented the riverine areas, along with the boat-billed heron (*Cochlearius cochlearius*), the night heron (*Nycticorax n. naevius*) and the most beautiful of the Paraguay herons—*Pilherodius*. Along the waterways anhingas or snake birds (*Anhinga anhinga*) were abundant, and the Brazilian cormorant (*Phalacrocorax olivaceus*) or "vigua" quite general, while the strange jacanas were much in evidence, running over river vegetation. The wild Muscovy duck (*Cairina moschata*) and several species of tree duck (*Dendrocygna*) were in numbers, the former particularly on the wet pantanal, flying up into trees when disturbed, but apparently passing much of their time in such situations. As the river sandbars became exposed a wealth of sandpipers, plovers and many skimmers (*Rhynchops nigra intercedens*) tenanted them temporarily.

On the dry pantanal the rhea or American ostrich was clearly the most interesting bird. It was usually met in small groups, generally in open treeless campo. It is to be hoped that the fate which in Argentina has overtaken this interesting genus of ratite birds will be prevented in southern Brazil, and that there it may be protected from the devastation of the feather-duster trade. Perhaps vacuum cleaners may be the rhea's salvation. Rheas can hardly be considered attractive from the standpoint of food, as their natural muskiness alone is unpleasant in the extreme. Their eggs are used as food by the natives and make a most acceptable omelet. The anomalous seriama (*Cariama cristata*), the sole representative of a family of debated relationship, is another most interesting campo inhabitant, as much an enemy of snakes as is the African secretary bird, which the seriama so much resembles. The turkey-sized screamer (*Anhima cristata*) perches on the top of some conspicuous tree and vocally advertises its presence.

The most brilliant of the conspicuous

land birds of the pantanal is the great hyacinthine macaw (*Anodorhynchus hyacinthinus*), the largest of American parrots, which, always in pairs and in groups of up to sixteen, raucously defies you and warns the entire district of your presence in their territory, as flying quite low, within gun shot, they circle above you again and again, until apparently tired they retire to some tall caapõe tree to talk it over among themselves.

Several other species of macaws, three of Amazon-type parrots and four species of parrakeets of several genera are regular in the pantanal, and all but one were seen by our party. Toucans of two genera (*Rhamphastos* and *Pteroglossus*), woodhewers of many types and ant thrushes of varied character, the glorious-voiced oven birds (*Furnarius*), and tanagers, finches, orioles and flycatchers of many genera made up a large part of the marked variety of the smaller land birds. A robin-like *Planesticus* suggested home, while at the next turn a gorgeous manakin dispelled that allusion. Contingas, however, were not seen, while swallows were not numerous in species. Woodpeckers were infrequent, but three species of kingfishers were abundant on the river, and a beautiful jacamar (*Galbula rufo-viridis*), very tame and confiding, was common in the open dry scrub forest.

The curassows were represented by quite a few species, one a great turkey-like *Crax*, while but two species of owl were seen, one a *Bubo*, the other a tiny *Glaucidium*. Of the hawks and the caracaras the variety was large and ranged from a tiny falcon smaller than a sparrow hawk to great brick-red hawks, but little smaller than some eagles. The everglade kite (*Rostrhamus sociabilis*), with its snail-eating habits, found much to feed upon in the literally millions of stranded *Pomacea* snails, left on every hand by the retreating flood waters.

About our headquarters the beautiful red-headed Brazilian cardinals of the genus *Paroaria* were abundant and trustful, while barn owls (*Tyto alba tuidara*) nested in the roof of the church at Descalvados.

The most abundant and evident large animal along the Rio Paraguay is the jacaré or caiman of that district (*Caiman* species). While not reaching the great dimensions of some of the species of Old World crocodilians, it makes up in numbers for its mediocrity in size. While the average adult is probably about eight to nine feet in length, they occasionally reach as much as twelve feet or even more. Doubtless jacarés are exceedingly destructive to all wild life as a whole, and are also responsible for the death of many cattle, particularly calves. Humans are not immune to their attacks, although they are not as generally dangerous to man as the African crocodile. Many men, however, have been maimed by them, and one of our party was seriously bitten in the foot by a jacaré while tramping in flooded pantanal. With them and piranhas as abundant as they are, swimming in the Rio Paraguay, or for that matter venturing in the larger areas of water any more than necessary, is not without perils.

Jacarés like crocodiles use sand-bars as sunning places, but also pull out on narrow bank shelves in the river forest. Often as many as a dozen will be found distributed along a short piece of river bank, but a foot or two above the water level. They are then quite sluggish and frequently several shots can be fired before the last survivors slide into the water. When in repose on land the head is kept raised, while in walking they raise themselves upon their legs and carry the body clear. Above in discussing the jaguar I have mentioned the extent to which jacarés spread over the pantanal when the latter is flooded. The Boreros eat the tail of the jacaré

after removing several long tendonous muscles.

Almost no lizards were seen at Descalvados during the dry season, and no chelonians except the great Brazilian land tortoise (*Testudo tabulata*), which was often encountered when hunting. The Boreros insist there are two species, one of which is very rare and much larger than the other. These animals, like armadillos, are regularly eaten by them. Armadillos are roasted whole, usually on a spit across the fire.

Of snakes the one most frequently brought to our attention was the rattlesnake or "cascavel" (*Crotalus durissus*). This is not at all scarce in the drier campo areas. The *Lachesis* type of pit vipers are also well represented, apparently by several species. We saw but few of these, possibly on account of the season. One of our hounds was bitten in the jowl by a poisonous snake, which was not seen. The two oozing punctures were soon surrounded by a rapidly augmented swelling, while the animal whined in pain. A prompt application of polyvalent antivenin had marked effect in ten hours, and the dog fully recovered in several days.

Few non-venomous snakes were seen except the anaconda, which locally is known as the sucuré. In size it does not reach Amazonian dimensions, the average individuals being not over ten feet in length. One large all black snake, possibly the famous mussurama, the foe of Brazilian venomous snakes, at Santa Rosa, not far from Descalvados, made an entirely unprovoked attack, coming for a considerable distance directly toward me, carrying the anterior part of the body well elevated. Just as I felt it would be necessary to stop the attack with a load of shot, the snake suddenly swerved, and sweeping about me disappeared in a hole in the ground. Two Indian boys who were with me fled, but returned to help locate the attacker, who, however, declined to leave his retreat. This snake was not less than eight feet in length. It reminded one, of course on a far larger scale, of the way our black snake will occasionally attack, but the Santa Rosa charge was without incentive, and my first knowledge of the snake's presence was its swift advance.

The fishes of the Rio Paraguay have furnished the subject for a number of the classical papers of Cope, Eigenmann and others. Needless to say, this fauna is tremendously rich in species, particularly of the highly specialized Characinidae. Even with all the previous work which had been done, the modest series of fishes taken by the expedition added four new species to science. Many of the fishes of the Rio Paraguay would be extolled in the highest terms for their angling qualities if they were better known and their habitat more readily accessible. Members of our party who were proficient with rod and reel had many experiences which would have made a salmon fisherman envious. The beautiful "dorado" (*Brycon hilari*), which is colored somewhat like, but far more brilliantly than, our striped bass, and fights with all the ability of a salmon, is common and runs from about six to nearly twenty pounds. The deep-bodied pacus (*Myleus*), which run to even greater weight, are just as powerful. The strange wolf fish (*Rhaphiodon typicus*), like the others a highly specialized characinid, possesses a pair of needle-like teeth at the end of the lower jaw, which lay over the face when the jaws are closed. In appearance and actions the wolf fish makes one think of a barracuda. The jaws of these fishes treat the angler's tackle much as a steel trap might, but if the leader and hook hold the fisherman will have all the thrills he can ask. The omnipresent piranhas (*Serrosalmus, Pygocentrus* and *Pygopristis*) are the fish menace to vertebrate life in Neotropical rivers. Much

has been written about them, probably many overstatements made, but they are undoubtedly the most justly feared existing fresh-water fishes. Whether their attacks are diverted or encouraged by agitation of the water remains unsettled, but there can be no question that a wounded or disabled man or beast falling into their home waters is frequently attacked and, unless able to get out of their reach, soon devoured or at least seriously injured. The taste of blood in the water seems to be the chief cause of their prompt concentration at any given point. I often have set afloat the skinned bodies of birds, and generally in an incredibly short time the piranhas were at them. In the ferocity of their attack they would sometimes leap clear of the water. In but a few minutes bones alone remained, when the bodies were moored so that results could be noted.

Piranhas do not readily take a hook, but when they do their triangular interlocking teeth play havoc with tackle. We trapped many in a cage trap, and used them for food. Captive young jaguars were frequently fed on them, and it is probable that, under certain circumstances, they may constitute part of the varied natural food of these cats. Piranhas must be stunned or killed by a blow before being handled. They are very tenacious of life, and if laid in the bottom of a canoe, without this precaution, they are able to vault their bodies into the air, and snapping teeth are thus a constant menace as long as life lasts.

The two most striking fresh-water mollusks of the Paraguay at Descalvados are *Pomacea insularum* and *Marisa planogyra*, the latter described from the expedition's collections. The dead shells of both literally pave great areas of the pantanal, particularly those sections which are more deeply inundated during the flood period. I have seen few living ones of either, stranded or in very shallow water, and it is difficult to secure living material, at least in the dry season. Most of the dead *Pomacea* have been punctured, apparently by the Everglade kite, which feeds upon mollusks. Few more remarkable resemblances exist than that between the adult *Marisa planogyra* and our well-known fresh-water genus *Planorbis*. I presumed I was collecting a very large *Planorbis*, which genus I know in our home streams. My colleague, Dr. Pilsbry, soon pointed out my error and showed me the ampullaroid type young. The flattened spirals of the adults may be nearly an inch and a half across. The bivalve mollusks were represented by the genera *Anodontites* and *Diplodon*, while doubtless numerous others would have been secured if time had permitted extensive search. Few land mollusks were noticed in the dry season, except for the large pink-lipped, white *Strophocheilus intertextus*, which was found dead in dense dry caapões. Living adults were probably safely hidden from the withering effect of many weeks of sizzling drought.

The dry season insect life was very scanty, being but an infinitesimal fraction of that I have found elsewhere in the American tropical and subtropics in the wet season. That the pantanal is rich in the wet season we know from the work of H. H. Smith at Corumbá. In the dry season there was not a single night producing the rich and varied flights of moths so frequently seen during the rains, but an occasional lone individual coming to our electric lights, the only illumination for many miles. Diurnal insects were inconspicuous and few, except for a limited number of small beetles and bugs. Wasps and bees were rare, except for colonies of the interesting black stingless bees *Trigona*.

Ants and termites were, of course, as generally evident as elsewhere in the tropics. The structures of the termites dotted many parts of the pantanal, par-

ticularly the campo areas. In height they reached as much as twelve feet, and in such cases were always slenderly conical and never domed.

The stridulating Orthoptera were little evident, although certain Acrididae were to be found in the dry campo, in open woods and the tall cover of wet pantanal—in the latter of the elongate type adopted for clinging close to a stem. A rough and shagreenous grasshopper of the genus *Ommexecha* preferred the dry ground of roads and trails, while equally protectively colored *Diedronotus* hopped among the fallen twigs of bush cover. The strange proscopid grasshopper *Cephalocoema,* which in its elongate form superficially suggests the walking-stick phasmids, was occasionally encountered in low bush, which also is the preferred habitat of many of its near relatives.

We have heard of the plan for keeping parts of Africa as permanent preserves to show the future what Africa was when white men came—how truly it is the Pleistocene carried on into our day. There is no fauna, except possibly that of Australia, more unique and distinctive than that of the Neotropical region. There are few places where this strange and ancient life remains as little disturbed and as readily seen as on the pantanal of the upper Paraguay. It is perhaps hoping too much that efforts may be made to conserve some of this wild land before the interesting mammals and birds, as well as other forms of the more conspicuous life, have been reduced to the vanishing point.

In the pantanal of the Paraguay we truly have the Neotropical vertebrate fauna more fully and abundantly represented, and by its most distinctive types, than in any single area of the lowland forests of South America.

MATHEMATICS DEVELOPED BY THE COMMON PEOPLE

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A STRIKING instance of the development of mathematics by the common people is the adoption of our common number system to the base 10. This is commonly assumed to be due to the fact that in early times people counted by means of their fingers and hence it has apparently no connection with the suitableness or the unsuitableness of the number 10 for this purpose. It is necessary to bear in mind the influence of the common people in the development of mathematics in order to explain such recent observations as the following: "I have tried, in other fields, to show the incredible confusions, of which the whole world is now one seething example, that followed from the invention by the Hindu mathematicians of negative quantities, and their justification from their analogy to debt."[1]

A part of these confusions are due to the fact that when negative numbers are used we have to admit that the ratio of a smaller number to a larger number can be the same as the ratio of a larger number to a smaller one, as results from the equation $-1/1 = 1/-1$. We have also to admit that a number can be less than zero, and hence that there are things which can be regarded as less than nothing. It is clear that as long as only positive numbers were used it seemed logical to say that the ratio of a smaller number to a larger one is always less than the ratio of a larger to a smaller, and that zero is the lower limit of the real numbers. Mathematicians naturally abandoned these views reluctantly, and even during the latter part of the eighteenth century there were some who argued that the use of negative numbers should be abandoned, since they seemed to lead to erroneous conclusions. The people, however, continued their use in view of the many advantages which this use presented, notwithstanding the fact that a clear theory of these numbers was then still lacking.

The use of negative numbers preceded a satisfactory theory thereof by many centuries and it now seems unlikely that the Hindu mathematicians contributed anything towards the establishment of this use in Europe. It is more probable that the European mathematicians began to use these numbers independently and later developed a theory which justifies this use. The Hindu mathematicians, however, deserve the credit of having used these numbers before they are known to have been used elsewhere, but their work along this line is not known to have had any effect on the later developments by the Europeans. In particular, the Arabs, who transmitted much of the early mathematical knowledge to Europe, did not adopt the negative numbers of the Hindus. In a certain sense negative numbers forced themselves on the attention of mathematicians in view of the simplifications which their use made possible and they therefore present a very interesting feature of the development of our subject.

It is well known that the ancient Greek philosophers at first considered it desirable to restrict the number concept to positive integers which exceed unity, as is illustrated by the following definition: "A number is a multitude of

[1] F. Soddy, "The Interpretation of the Atom," preface, 1932.

units."[2] This view was supported by such eminent philosophers as Plato and Aristotle. Notwithstanding the eminence of its supporters, it was gradually abandoned by various Greek writers who found it convenient to include unity among the numbers even if it has fundamental characteristic properties which led many others to regard it as the source of all numbers but not as itself a number. In particular, Theon of Smyrna (about 130 A.D.) asserted that unity is not a number, but soon thereafter he included it among the odd numbers as well as among the natural numbers.

This inconsistency on the part of Theon of Smyrna is typical of certain mathematical developments relating to questions in regard to which eminent authorities pointed one way and actual applications by the common people exhibited an easier way from the standpoint of these particular applications. Not only did unity thus secure an entrance into the number concept, but this concept had to be extended so as to admit the rational fractions, the irrational numbers, zero, the negative numbers, and finally the complex numbers. In fact, unity and the rational fractions had been accepted as actual numbers long before the ancient Greek philosophers endeavored to exclude them for the sake of securing thereby a simpler philosophical theory. The development of mathematics has frequently been dominated by the use made of it by the common people and not by the theoretical considerations advanced by the philosophers. The theory had at times to accommodate itself to the uses, since the uses failed to accommodate themselves to the proposed theory.

The late Felix Klein (1849–1925) expressed the influence of some such uses in the following words: "We have repeatedly emphasized what an important part in the development of the science has been played by the algorithmic process, as a quasi-independent, onward-driving force, inherent in the formulas, operating apart from the intention and insight of the mathematician, at times, often indeed in opposition to them. In the beginnings of the infinitesimal calculus, as we shall see later on, the algorithm often forced new notions and operations, even before one could justify their admissibility. Even at higher levels of the development, these algorithmic considerations can be, and actually have been, very fruitful, so that one can justly call them the groundwork of mathematical development. We must then completely ignore history, if, as is sometimes done to-day, we cast these circumstances contemptuously aside as mere formal developments."[3]

The algorithms connected with the solution of the algebraic equation constitute one of the clearest illustrations of these remarks. Some writers have expressed the view that even the ancient Babylonians, about 2000 B. C., observed that some quadratic equations have two roots, and hence that equations which explicitly involve only one unknown may actually involve more than one. No instance is, however, yet known where it was explicitly stated before the beginning of the Christian era that a given algebraic equation is satisfied by more than one number and hence may yield more than what was explicitly put into it. While the ancient Babylonians solved certain quadratic equations according to the modern formulas and made some progress in the solution of cubic equations these algorithms remained fruitless as regards the extension of the number concept not only in their hands but also in the hands of the an-

[2] Book VII, Euclid's "Elements."

[3] "Elementary Mathematics from an Advanced Standpoint." Translated into English from the German by Professors E. R. Hedrick and C. A. Noble, University of California, Vol. 1, page 79, 1932.

cient Greeks during their golden period of mathematical development at the time of Euclid, Archimedes and Apollonius.

The first fruits as regards the extension of the number concept to which the solutions of quadratic and cubic equations contributed largely relate to the irrational and the negative numbers. It has recently been established that the theory of the former, which was developed by Eudoxus (about 410–356 B.C.), differs only formally from the modern theory, commonly known as the Dedekind cut. This theory has a remarkable history, since it constitutes probably the only instance in the history of mathematics where a sound doctrine was abandoned for two millenniums because it was opposed by one man. In the present case it was Aristotle who used his strong influence so successfully in opposition to what appears to us now as a satisfactory doctrine of irrational numbers, but his influence could not deter the common people from using these numbers without a satisfactory theory therefor, just as they used negative numbers for a long time before the development of a satisfactory theory relating thereto.

The late H. Poincaré stated in an address read at the Rome international mathematical congress, 1908, that "mathematics is the art of giving the same name to different things." For instance, the number concept originated from the counting of similar objects, but it was extended in prehistoric times to the counting of dissimilar ones, as is illustrated by the fact that in the ancient Egyptian Rhind Mathematical Papyrus (between 1788 and 1580 B.C.) such different objects as houses, cats, mice, etc., are added and that a special word for the abstract unit appears therein. This primitive counting origin of the number concept is very different from the modern concepts of irrational and complex numbers, which have no direct connection with counting. If the question is asked why the mathematician uses the same name for such different concepts and thus in a certain sense has brought "incredible confusions" into his subject, it should be noted that the confusions would have been still greater if he had failed to follow here the pragmatism of the common people. The common properties of the different kinds of numbers have been found to outweigh their diversities in actual applications. This was not the discovery of a few men, but the resultant of tendencies which were frequently conflicting and denounced.

The philosophers have done much towards establishing order in mathematics, but they have been most successful when they followed the lead of the common people. When they tried to limit the number concept, as the ancient Greeks did, they hampered the onward march of mathematical progress instead of contributing thereto. It is only natural that the devotees of this subject have at times been perturbed as regards its future. Already in 1869 H. Hankel was led to compare mathematics with the Tower of Babel because the mathematicians speak such different languages, and in an addendum to his well-known "Erlanger Programm," Felix Klein remarked that the extensive confusion of languages in mathematics appears to have a serious but undesirable tendency towards the self-blocking of all mathematical progress. Fortunately, such unifying and clarifying notions as functions and groups tend to simplify the mathematical language and also to embody experiences of the common people.

The ancient Greek term "geometry," which is etymologically equivalent to our modern term surveying, exhibits that the practical needs of the common people contributed towards the development of this large branch of mathematics. Recent discoveries relating to ancient

Babylonian mathematics show that the intellectual needs of these people made themselves felt in very early times, since they include geometric problems which seem to imply a knowledge of the so-called Pythagorean theorem long before Pythagoras was born. In fact, the oldest extant Babylonian mathematics is largely pure mathematics and shows that the mathematical interests of the people, even in those early times, were inspired by a desire to understand the nature of imaginary situations which are not likely to arise in practical life, including the use of such a large number as $195\,955\,200\,000\,000 = 60^8 + 10.60^7$. It is a great mistake to assume that the common people have been interested only in applied mathematics. The history of the pre-Grecian civilizations seems to imply that they were, however, not much interested in rigorous proofs according to modern standards.

The most important difference between the mathematics of the common people and that of the philosophers is that the former is based upon implied postulates, which are not necessarily independent, while the latter employs explicit postulate systems and aims to reduce the number of the postulates to a minimum. In both cases the correctness of the results depends upon the correctness of the postulates, and in both cases the confidence in the correctness of these results has the effect of producing a feeling that eternal truths are under consideration. The geometric developments of Euclid's "Elements," which are explicitly based upon a system of postulates, inspire no more confidence than the table of unit fractions which appears in the older Rhind Mathematical Papyrus, where no such system appears. The modern student of elementary mathematics who is inclined to reflect on the nature of these courses may be helped by bearing in mind that both the common people and the philosophers have had a share in providing the mathematical material with which he is confronted.

With the advent of printing mathematics as well as the other sciences became more and more enslaved to books, and the development of mathematics became more and more largely confined to those who studied these books. With the increase in the number of available books cooperation in the advancement of our subject became more efficient. One type of cooperation is represented by the mathematical societies, and it is interesting to note that the common people took an active part in the early organization of such societies. The oldest of these which has survived through more than two centuries is the "Mathematische Gesellschaft zu Hamburg," organized in 1690. During the first hundred years of the existence of this society the most learned mathematicians of those times failed to join it, so that its membership was composed largely of common school teachers, bookkeepers, merchants, etc. The great advances made during this period in the development of analytic geometry and the calculus were not due to members of this society and were not promulgated by them.

A noted early English mathematical society was founded at Spitalfields in 1717 and was taken over by the Royal Astronomical Society in 1845. This was at first little more than a workingman's club at which questions of mathematics and natural philosophy were discussed every Saturday evening. Each member present at a meeting was entitled to a pint of beer at the common expense, and it was the duty of every member who was asked a mathematical or philosophical question by another member of the society to answer the question to the best of his ability. The society accumulated a valuable library and its rooms became headquarters for

lectures on various scientific subjects. While it later included among its members some of the leading English mathematicians it is mainly interesting in the present connection in view of the fact that it was organized by the common people and exhibits the influence of these people on early organizations of mathematicians.

The secondary base 60 which appears in our tables relating to the measurement of time and of angles can be most easily explained in accord with the known historical facts by assuming that the ancients selected it in order to assist the common people to avoid the use of common fractions. The numbers $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, were commonly represented by the ancient Babylonians by 30, 20, 15, 12, 10, respectively. The primary base 10 is not well suited for the avoidance of common fractions, since even $\frac{1}{3}$ and $\frac{1}{4}$ do not appear as integers when this base is used. It is a very singular fact that the ancients failed to employ a symbol corresponding to our modern decimal point, which enables us now to avoid the use of common fractions. While every real number can be represented as an infinite decimal number, comparatively few of them can be represented as a finite decimal. Those which can be thus represented are, however, of special historic and practical interest. They obviously are equivalent to the common fractions whose denominators involve only powers of 2 and 5. The base 60 is much better adapted than the base 10 for the avoidance of common fractions, but even $\frac{1}{7}$ does not correspond therein to a finite integer when the point corresponding to our decimal point is omitted. Hence the modern student of mathematics naturally finds it difficult to explain the extensive use of the base 60 in ancient times and its persistence in our modern tables. Such difficulties point, however, to the influence of the common people on the development of our subject and provide material for harmonizing hypotheses.

One of the noteworthy features of the development of mathematics is that it has restricted the field of the puzzles, which have always interested the common people. The Indian mathematician Brahmagupta (born 598) is said to have remarked near the end of his algebra that "as the sun obscures the stars so does the proficient eclipse the glory of other astronomers in an assembly of people by the recital of algebraic problems, and still more by their solution." The hau or "aha" problems of the Rhind Mathematical Papyrus have sometimes been called puzzle problems, and it is probable that they were at first regarded as such, but they now may be regarded as linear equations in one unknown and hence they come under a well-known general algebraic theory. The first of these is problem 24 and reads as follows: "A quantity and its $\frac{1}{7}$ added together become 19. What is the quantity?" The puzzles presented by individual problems cease to be puzzles when it is recognized that they come under general theories and hence the development of mathematics tends towards the eradication of various puzzles which were sufficiently elementary to interest the common people.

While the sense of discovery has probably always furnished one of the most forceful inspirations for mathematical study, the growth of the mathematical literature naturally tends to make it more and more difficult to determine whether these discoveries are actually new and are not involved as special cases of a general theory. The common people are thus deprived more and more of the incentive furnished by the feeling that they can make actual contributions towards the advancement of mathematical knowledge. This is probably not the most serious obstacle towards the maintenance of their keen

interest in mathematics. The feeling that they might be regarded as ignorant if they expressed their views to those who enjoyed better advantages to become acquainted with what is well known is probably a more serious deterrent factor on the keen interest of the common people in advancing science. The difficulties involved in securing the necessary knowledge to understand the nature of the modern developments in comparatively new fields are naturally viewed with some misgivings by those who realize that the effectiveness of scientific knowledge depends largely upon a wide-spread understanding and use thereof. This is especially true of such a basic and abstract science as mathematics aims to be.

The influence of the common people on the adoption of tables of weights and measures and on the problems of commercial arithmetic is noteworthy. The Liber Abbaci (1228) of Leonardo of Piso is one of the most favorably known early works in which commercial problems receive much attention. The date of this work presents an unusually interesting question as regards the importance of being acquainted also with the secondary sources of historical information. The date on the extant MS is 1202 and the histories of mathematics which are now most widely used in our country give this date notwithstanding the fact that it has been proved that it can not be correct. The question is considered in particular, near the beginning of volume 2, M. Cantor's noted "Vorlesungen über Geschichte der Mathematik." It is, therefore, useless to cite the original source, as is sometimes done, to justify the use of the date 1202 for this particular work, and in this particular case it is more important to be familiar with the secondary sources of information than with the original, although the contrary is probably more commonly true if one can be acquainted with only one of these sources.

THE PLACE OF SOIL IN THE BIOLOGICAL COMPLEX

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Soil science, as an independent discipline, is of rather recent origin as compared to other branches of knowledge. Before 1870 the study of soils was only more or less incidental in various other fields, such as chemistry, botany and geology. As geology became an established discipline with a growing body of information regarding the nature of rocks and with methods for studying rocks and their weathering products, scientists in this branch took some interest in soils. Many of these studies were fruitful, *provided that they were confined to a small area;* that is, in an area having essentially uniform climate, vegetation, age and relief, any differences in parent rock would frequently give rise to differences in soils. But these differences were difficult to interpret in terms of native or cultural plants.

It was observed that if a section were made through any soil it is made up of several layers, or horizons, called, collectively, the soil profile. And unlike the layers in a body of sediments, a genetic relationship exists between the horizons of the profile: they evolved together. It was further observed that whereas rocks occurred quite promiscuously all over the world, soil types were limited to rather definite geographical areas. Thus, for example, the Podzols, the Chernozems and the Laterites were found only in certain distinct climatic and biological regions. With the recognition of this definite element of geographicity of soils came the conception of soil as an independent natural body. The naturalist was now in a position to study the soil from an entirely scientific point of view without being restricted to practical investigations. Thus a new discipline arose about 1870—pedology.

From a consideration of this principle of geographicity there follow several important deductions regarding the influences in operation during the genesis of a soil. As the chief factors of climate are rainfall, temperature and relative humidity, it will be obvious that these influence the amounts of various chemical elements and compounds in the soil; and further, that any influences which bear upon these climatic factors will be reflected in the soil. For this reason it is clear that soils will be influenced by vegetation and relief which modify the conditions of moisture and temperature. And, as the process is essentially one of evolution, time will be important. As the cooling and moistening of the surface depend somewhat upon the nature of the underlying rocks, and as extremes in chemical and mechanical composition of the rocks will influence the salts in the soil, it is clear that the parent rock will need consideration. A graphic illustration of these factors could be shown thus: Soil = f (Climate, Vegetation, Relief, Age, Parent Rock).

The Development of Parent Material

The first step toward the development of a soil is the accumulation of parent material. Weathering proceeds under the influence of physical and chemical forces. The action of wind, moving water, ice and temperature changes act to disintegrate large masses of rocks. Under the chemical influence of water, carbonic acid and oxidation-reduction reactions the chemical composition of the

rocks is altered. Of course, some of these actions are going on in the soil, but here they are merged with other forces of greater magnitude. These chemical changes during weathering are quite similar under different climatic régimes, but external differences, especially temperature, determine the rate and the direction of the reactions.

The greatest mass of the mineral matter in rocks is composed of silicates and alumino-silicates. Such rocks as limestones contain, of course, the alkaline earth metals in the carbonate form, but most of the cations (*i.e.*, ions having a positive charge) exist in the rocks combined with silicic and alumino-silicic acids. Under the weathering processes these salts are hydrolyzed to form the alumino-silicic acid and the carbonate of the cation, thus:

$$K_2O \cdot Al_2O_3 \cdot 6SiO + 3H_2O \rightarrow 2KOH + 2H_2O \cdot Al_2O_3 \cdot 2SiO_2 + 4SiO_2$$

$$2KOH + H_2CO_3 \rightarrow K_2CO_3 + 2H_2O$$

The carbonates of iron and manganese are unstable and decompose to the oxides. By various interrelations many anions and cations combine to form other salts, such as sodium chloride, potassium sulfate and a host of compounds varying greatly in solubility. These are removed or are accumulated, depending upon the degree of moistening and the position of the water table. The weathering process goes on under essentially sterile conditions and should in no sense be confused with the formation of soil.

The Genesis of Soil

Some time after the accumulation of parent material there is an introduction of living matter. As respects soil, living matter presents two different aspects: (1) synthesis and (2) decomposition. For the purposes of general consideration there are two great groups of plants which synthesize organic matter, grasses and trees. Of those which decompose organic matter there are: (1) the higher animals, (2) anaerobic bacteria, (3) aerobic bacteria and (4) fungi.

The optimum conditions for the growth of these several classes of organisms vary widely between classes. Further, the different classes of micro-organisms which decompose organic matter give rise to quite different products. (Of course, the ultimate end products, where the processes go to completion, would be essentially the same: namely, carbon dioxide, water and ash; but the products found in the soil at any moment are quite different.) The organic acids, and their salts, produced through the activity of fungi, are quite soluble; while those resulting from bacterial action are relatively insoluble. Thus the two classes of micro-population have entirely different influences in the development of soil.

Before examining the influence of a biological community in the development of soil the nature of the colloids in the soil should be briefly considered. These colloids, which have been called the "protoplasm of the soil," are of two general types: (1) the inorganic, which constitute the fine portion of the clay, are made up of alumino-silicates resulting largely from the partial weathering of the feldspar minerals; and (2) the organic, which are chiefly composed of lignin and result from the decomposition of organic matter. These colloids absorb cations by the ordinary base exchange reaction, according to the relative concentration of the various cations present; and their properties vary enormously, depending upon which cations are absorbed. There are three principal types which may be designated as the hydrogen-colloid, the sodium-colloid and the calcium-colloid. In the absence of flocculating electrolytes the hydrogen-colloid is acid and easily dispersed into colloidal suspension; the sodium-colloid

is highly alkaline and is the most easily dispersed; while the calcium-colloid is mildly alkaline and remains in a flocculated state. Obviously, the first two can be easily leached from the surface soil, while the calcium-colloid will not be so leached. These mobile colloids may be flocculated in a lower horizon giving rise to a layer high in its percentage of clay. Such a layer, called the "B" horizon, is frequently indurated into a sort of sandstone in the case of the Podzol.

The Soil-building Processes

Depending upon the nature of the environment, there are three principal types of soil formation—calcification, podzolization and laterization. The calcification process is maintained under conditions of restricted rainfall. There is some leaching, but not enough to remove the carbonates of the alkaline earth metals and they accumulate in some horizon of the soil profile. The vegetation consists of grasses, or grass-like plants, which are heavy feeders on the bases, especially calcium. The prominent organisms are bacteria.

Under such conditions the plants bring bases from the lower to the surface soil in such large amounts that the colloids, both organic and inorganic, remain flocculated. The products from the decomposition of the organic matter by bacteria are relatively insoluble and remain in the upper part of the soil. It might be added then that this soil process conserves those elements considered as essential for the growth of crop plants. In the accompanying sketches are shown two important examples of soils developed under such conditions—the Chernozem and the Sierozem. The Chernozem is developed under conditions of sufficient moisture to give a luxuriant grass vegetation with the accumulation of a large amount of organic matter, while the Sierozem approaches the desert. Intermediate between these two are the Brown soils. The great wheat lands of the Americas and of Russia are found on the Chernozem and Brown soils.

The podzolization process of soil formation is dominant throughout the humid regions but especially in the more northern part. Here there is sufficient moisture to remove the soluble salts, both of the alkali and of the alkaline earth metals, completely from the soil. The chief vegetation is forest and the most prominent organisms are fungi. Forests are not as heavy feeders on bases as are grasses. In this respect there is a great difference between the coniferous trees and the deciduous trees. The conifers feed very lightly on bases, shed their leaves slowly and, due to their resinous nature, these leaves and twigs decompose more slowly than do those of the deciduous forest. Because of the toxic action of the tannins from the trees on bacteria and because of the low content of bases the fungi are more prominent and the products of the decomposition of the organic matter are relatively soluble.

As the trees do not furnish enough bases to the surface of the soil for the complete neutralization of the carbonic acid dissolved in the rain water, the base exchange colloids, both organic and inorganic, become saturated with hydrogen. In this condition the colloids are easily dispersed and are leached downward into the lower horizons of the soil profile. Further, the iron appears to be in the reduced form near the surface in the presence of the organic anions (*i.e.*, ions having a negative charge) resulting from the decomposition of the organic matter. This reduced iron moves downward in true solution, but as it passes out of the influence of the soluble organic matter it is oxidized and precipitated in the lower horizons.

Thus in the case of the Podzol developed under extreme podzolization, an entity entirely different from the Chernozem is produced, even from the

identical parent material. The surface of the Podzol has been impoverished of bases, nitrogen and colloids. The soil is highly acid throughout. Almost nothing but silica remains in the white, leached horizon near the surface, while a more dense horizon in which iron and alumina have accumulated underlies it. Naturally, such a soil is considered infertile for the ordinary plants cultivated for human food, even though it supports well a native vegetation that has evolved with the soil.

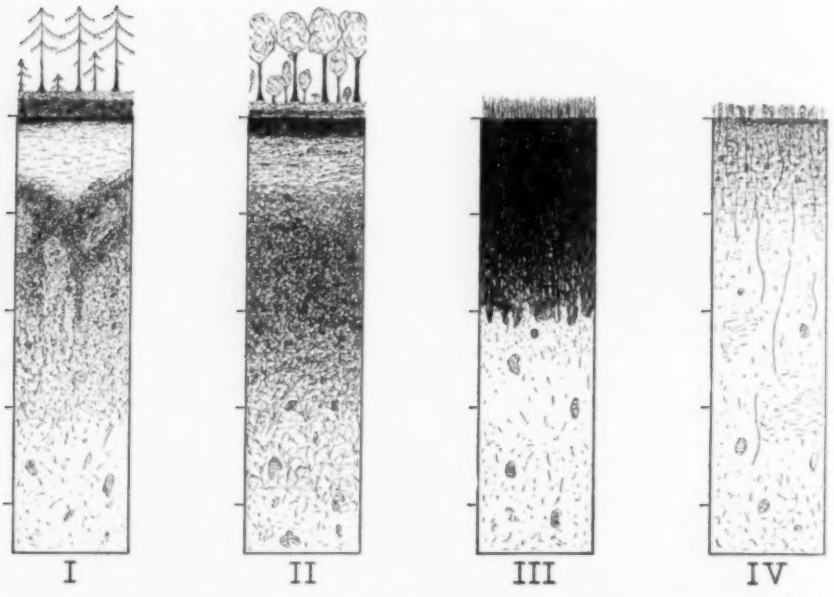
The great soil zone immediately south of the Podzol has been, until recently at least, the most important since the days of the old Roman Empire. Our present western civilization is largely developed on these Gray-Brown Forest soils. The climate is similar to that of the Podzol, except for the higher temperature. The forest is chiefly of deciduous trees. As the leaves are shed every year there is a greater mass of material deposited on the soil from these plants than from the coniferous trees; and further, the deciduous trees are heavier feeders on the bases, especially calcium, than are the pines and spruces. Thus, more bases are returned to the surface of the Gray-Brown Forest soils and they do not become as highly acid as do the podzols. Although these soils are developed under the same podzolization process, it is less intense and the surface horizons contain more organic matter and more nutrient elements. The soils are, of course, much less fertile for most crop plants than the Chernozem, but more fertile than the Podzol.

The laterization process, peculiar to the Laterite soils, is operative under the extreme moistening and high temperatures of the tropical climates. The weathering process under which the parent material accumulates is very intense. The hydrolysis of the minerals goes on very rapidly, such that the solution around the individual particles of mineral is neutral or slightly alkaline in reaction. Further, the vegetation grows and decomposes very rapidly, bringing bases to the surface in large amounts. Under the influence of this alkaline reaction the silica becomes soluble, especially the silica of the alumino-silicic complexes. But the iron and alumina are resistant and remain. Hence there is developed a parent material for soil, consisting largely of iron oxide and alumina with quartz silica, manganese and resistant compounds of less importance. After hydrolysis has gone nearly to completion, the bases are so depleted that further weathering results in an acid reaction in the soil. As soon as the soil becomes acid the podzolization process becomes impinged upon the material accumulated through laterization.

There may be said to be 13 of these great soil zones, of which 4 of the most important are shown in accompanying sketches. Each of these has developed under a particular set of conditions of climate, vegetation and relief. Further subdivisions within the group exist as a result of differences in age and parent material.

The Biological Complex

In the study of any phase of the landscape—plants, soil or animals—it is of the utmost importance to appreciate that the landscape has evolved as a whole. The present state of any soil, or of any other part of the landscape, represents an equilibrium between many forces. It is continually moving—dynamic. Any change in climate or vegetation immediately upsets the biological equilibrium and the system starts moving in the direction of another equilibrium point. Although the climate and vegetation are the most directly noticeable and, in general, the most commonly important phases of this biological complex of which the soil is a part, many less obvious features are important and may



	I Podzol	II Gray-Brown Forest	III Chernozem	IV Sierozem
Profile	A very thin organic layer lies on top of gray leached soil which is over a dark brown horizon.	A rather thin organic layer lies over grayish-brown leached soil which is over a brown horizon.	Black soil, grading into a whitish calcareous horizon.	Grayish soil, grading into lighter calcareous material.
Vegetation	Coniferous forest	Deciduous forest	Tall grass prairie	Short grass and desert plants
Climate	Cool Moist	Temperate Moist	Temperate to cool Semi-arid	Temperate to cool Arid
Fertility (crop plants)	Low	Medium	Very high	Medium to high if irrigated

Sketches of the Profiles of Four of the Great Soil Groups. These sketches show the great differences in the profile character of mature soils in equilibrium with different biological complexes and developed from identical parent material. Each section is 54 inches in depth.

change the entire procedure. Itasca Park in Minnesota can be cited as an example: This area was set aside by law to remain in the "natural state." The destructive works of fire and man were to be controlled and the area allowed to develop in a natural way as an example of the normal biological complex of the region. It was thought expedient, however, to destroy the wolves, which prey, not only upon the animals in the park, but also upon the live stock of nearby farms. Since the wolves were the natural predators of the beavers and the deer, these latter species have accordingly increased enormously. Competition for food among the animals has resulted in the destruction of the aspen trees near all the lakes and streams by the beavers and of the young pine reproduction by the deer. Such a change in vegetation has also, of course, upset the normal soil development in the area. This case has been mentioned merely to

illustrate the delicate balance which exists between various parts of the biological complex—the whole is one evolutionary complex.

Man himself is a part of this complex. Obviously man's activities upset the conditions which would exist in his absence. But if man is considered as any other organism, adjusting himself to his environment as best he can, then man is in a position fundamentally like that of any other organism of the complex. Considered in this light, the changes made by man are normal changes.

Of great importance to man are the adjustments which he himself makes according to the biological complex in which he finds himself. That the folk songs and other cultural attributes of man bear a direct relationship to the landscape in which they are developed is well known. In man's struggle for food and shelter, adjustments of far-reaching social consequences are made. Those plants which are grown for human food and for the food of domestic animals are rather limited. Naturally those plants and animals which most nearly approach the native organisms that formed a part of the biological complex will develop the best. The cereals may serve as an example. These grass-like plants are similar to the native grasses of the Chernozem, but they are very unlike the forest, especially the coniferous forest of the Podzol zone. It is said, therefore, that the Chernozem soils are more fertile than the Podzol soils. This is true only in respect to certain plants. Certain other plants, such as pine trees, find their best (most fertile) soil among the Podzols. Each of the great soil zones is most fertile for certain plants. But the plants which man raises for food are, for the most part, quite unlike those native to the Podzol, Gray-Brown Forest and several other of the great soil zones. Man must then alter the soil which is fertile for pine trees in order to grow other plants which he wants. But he need only plow the ground in the Chernozem and Brown soil zones. Other comparisons of like nature could be made regarding domestic animals and wood for fuel and shelter. As a result man constructs quite different economies and quite different social structures on the various soils.

It is, therefore, of the greatest importance that soil be recognized as one of the factors in the biological complex and studied from that point of view. It is a natural entity in itself, having its own special morphology and dynamic, and developing with the landscape of which it is a part. These various soil entities, produced through the sum total of the climatic and biological forces impinged upon them, have certain possibilities and certain limitations for the development of man. Like any other part of the complex man contributes an influence upon the complex and also he is fundamentally influenced by it.

THE DISPLAY OF WALLACE'S STANDARD-WING BIRD OF PARADISE IN CAPTIVITY

By Dr. HERBERT FRIEDMANN[1]
CURATOR OF ORNITHOLOGY, U. S. NATIONAL MUSEUM

WHEN one finds a bird of unusual plumage combinations, very plain save for a localized brilliance of color or singularity of plume, the question arises as to how the bird utilizes its peculiarities in its display. It is obvious that the display is the chief, if not the only, opportunity for use of such characters as elongated plumes, bright gorgets, etc. Among all the birds of the world none are more abundantly supplied with plumage modifications of a purely display type than the birds of paradise, and among these remarkable creatures none is more bizarre or aberrant than Wallace's standard-wing.

The male Wallace's standard-wing is a dull earth-brown bird with a large brilliant emerald green pectoral gorget extended into a free V-shaped apex about five or six inches long on either side, and with two peculiar, whitish, narrow-webbed and terminally spatulated, erectile feathers on the upper surface of the carpal angle of each wing. (Fig. 1.) The female lacks the green gorget and the whitish plumes, and is wholly dull earth-brown. The species is extremely rare in captivity, and, as much of our knowledge of the displays of birds of paradise is based on observations of caged birds, it follows that little is known of the courtship poses of the present species. In fact, a search through the literature has failed to reveal a description of the display antics of Wallace's standard-wing.

The National Zoological Park in Washington is fortunate in possessing a splendid male of the Halmahera race

[1] Published by permission of the secretary of the Smithsonian Institution.

FIG. 1. RESTING POSTURE

of Wallace's bird of paradise (*Semioptera wallacei halmaherae*). This bird, which has lived there now for about two years and which is in good health and perfect plumage, was recently observed displaying. Mr. E. P. Walker, assistant director of the park, who was with me at the time, was as much surprised as I to see the way in which the bird displayed. I made several subsequent visits to the bird to get more detailed notes, and accelerated its activity by bringing with me a skin of a female and of another male from the museum and displaying them to the captive. Later Mr. R. Bruce Horsfall, artist of *Nature Magazine*, went out to the park with me and made the sketches which illustrate this paper. I am greatly indebted to Mr. Horsfall for his kindly cooperation.

My notes on the display may be summarized as follows.

The first indication of approaching display is a change in the posture of the bird. Instead of sitting in the usual semi-erect pose, it bends over forward or heads down a branch so that its head is lower than its body; sometimes even lower than its feet. (Fig. 2.) Then it gives a few harsh, rasping *tscharrrr* notes in rapid succession; then flaps its wings three or four times rapidly, the wings not more than half open at any time in the flapping. (Fig. 3.) After a few such wing beats, which, if the bird were sitting upright, would be quite comparable to the first beats of a grouse's wings (*Bonasa umbellus*) when

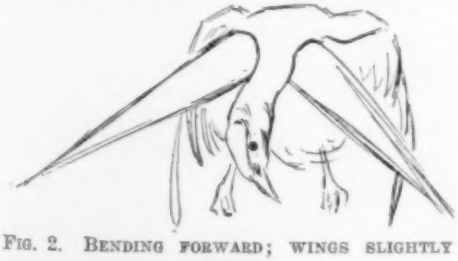


FIG. 2. BENDING FORWARD; WINGS SLIGHTLY ARCHED

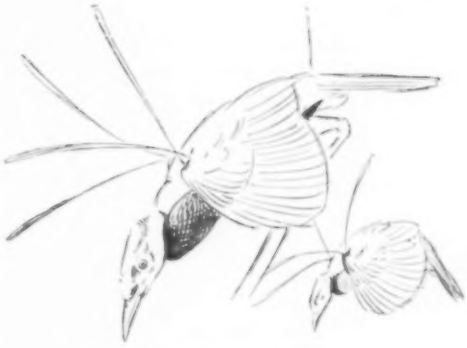


FIG. 3. BEGINNING OF USUAL DISPLAY; WINGS VIBRATING; CARPEL PLUMES ERECTED.

starting to drum, the bird suddenly holds the wings arched horizontally, and the entire body then quivers or vibrates for a fraction of a second. (Fig. 4.) The wings are held so that they may actually touch (or nearly so) at the wrists. The elongated white carpal plumes are erected with the first rapid wing beats and remain so now, and the inner ones of each wing actually cross in the air above the body of the bird. Occasionally both the inner and the outer pairs cross each other, but more frequently only the inner ones do so. The green gorget is sometimes only slightly raised, but in full displays it is completely elevated away from the body

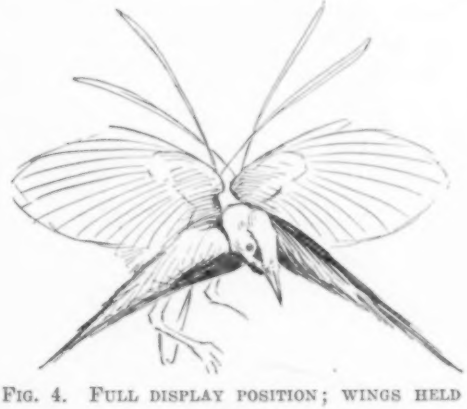


FIG. 4. FULL DISPLAY POSITION; WINGS HELD STILL.

except, of course, medially, and the two lateral attenuated apices are brought forward out on the sides. The short velvet-like feathers of the crown are ruffled and, when reflecting light, give an optical effect of a rolling beam of light traveling from the forehead to the occiput. While this pose is held the bill is kept closed, but the bird utters a series of low, guttural, almost whisper-like sounds like that of faint cracking of twigs. The throat dilates slightly as the successive notes are given.

The display may end here with the folding of the wings back to their usual position and the resumption of a normal upright posture, but two types of elaboration are often indulged in. Probably the displays that terminate here are incomplete.

In the first type the wings are suddenly stretched out fully horizontally, bringing the carpal joint (the point of attachment of the white plumes) far out laterally, and are held stiffly in that position for a second or two. The white plumes are still erected individually. (Fig. 5.) From a front view of the bird it looks almost as though the white plumes on either side were attached to the apical areas of the green gorget, which is held widely stretched at right angles to the body. The head may be raised somewhat during this stage, but the bill always points downward. The wings are soon folded, the plumes slowly fall, the gorget relaxes and subsides, and the display is over. In some cases the wings are not stretched laterally, but merely stiffened. (Fig. 6.)

FIG. 5. WINGS STRETCHED LATERALLY AND HELD MOTIONLESS.

In the second type, the bird keeps the wings half arched and then leans backwards on its perch, presenting to the female a view of the gorget and the whitish plumes hovering behind it. It may let go of the perch and tumble over in the air in a backward somersault, landing on its feet with closing wings. This ends this type of display. The former type was much the more frequently indulged in in my experience.

Aside from the green gorget and the erectile carpal plumes, the antics of the bird in the first part of its display—bending over and arching the wings—is slightly reminiscent of the display of some of the Icteridae, but presents the following points of difference. The tail is never spread and is usually depressed, not elevated, in *Semioptera;* it is always raised and usually spread to some extent in the Icteridae. In *Semioptera* the bird bends over before arching the wings; in the Icteridae the wings are arched first. The guttural twig-cracking sounds are peculiarly like those made by some of the oropendolas (*Gymnostinops montezuma* and *Ostinops decumanus*).

It occurred to me that possibly in a wild state the displaying male would assume a position in the tree above the female to which he was displaying, and that this might account for the downward posture assumed before the real inception of display. I tried, therefore, putting the skin or skins, that I used to help excite the bird, on top of the cage, above his perch, etc., as well as below it, but the head-lowered position was not affected in any way by these changes. If the origin of this pose was as suggested, then it has become so stereotyped in its performance that it is no longer easily altered. Occasionally the

FIG. 6. POSITION 4 EXAGGERATED BY SUDDEN MUSCULAR TENSION

bird may bend downward so far that it is upside down when displaying.

On one occasion, at the height of the wing-arching stage, when the wings were almost touching at the carpal joint, the bird uttered a rolling almost trilling series of notes quite different from the rasping *tscharrr* or *arrrrh* notes given before the actual display. These individual notes were of the *arrrh* type, but clearer, shorter and less nasal in quality. Usually, however, the bird is silent while displaying, save for the faint twig-cracking sounds.

In all types of display, the white carpal plumes remain erect for a little while after the wings have been folded. It looks as though the tension required to raise them needs time to die down; that the bird can elevate them quickly but can not force them down as instantaneously.

SCIENCE SERVICE RADIO TALKS

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HOW WE REMEMBER

By Dr. SAMUEL W. FERNBERGER

PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF PENNSYLVANIA

I SUSPECT that there is not one of my listeners who has not recently mislaid something and who can not for the life of him remember where he put it. Or perhaps you have forgotten a name which you wanted to remember, or you have forgotten some important fact. It is a popular belief that forgetting of this sort is more true of old age. How often does one hear it said: "I must be getting old because I can't remember so and so." As a matter of fact such forgetting is perfectly characteristic of all ages. I hope before I am through to indicate how it is possible to improve your ability to remember.

Indeed the experimental results from the studies of learning and forgetting indicate that the situation is rather worse than most people suspect. The first experimental study of forgetting and remembering was performed less than 50 years ago, but since that time, there is probably no problem in experimental psychology which has been investigated in so many phases and on which so much time has been spent.

The results of the first study of forgetting, which was reported in 1885 by Hermann Ebbinghaus, indicate as well as any other how serious is this matter of forgetting. Before I indicate the results, let me briefly outline the experimental method. Ebbinghaus learned lists of nonsense syllables like some of those which have recently appeared in advertising. These lists of nonsense syllables were learned only to the point at which they could be first correctly repeated. Then periods of time were allowed to elapse ranging from 20 minutes to 30 days in order to determine the degree of forgetting for the different periods of time. When the testing of the amount forgotten was to be determined, there was no attempt to recall the series. Instead the series of syllables was relearned and the amount of time and the number of repetitions saved in relearning gave an index of the amount remembered.

Under the conditions, then, of learning lists of nonsense syllables to the point of first errorless repetition and testing the amount forgotten by the method of relearning, it was found that, after 20 minutes, more than 40 per cent. was forgotten; after 1 hour, more than 55 per cent. was forgotten, and after 6 days only about 25 per cent. was remembered. That is indeed a discouraging picture. Think of the teacher, for example, who may expect that more than half of a lecture will be forgotten one hour later and more than three quarters of what is taught on Monday will be gone by the following Monday.

Undoubtedly all of you have already thought of a number of criticisms, but I can assure you that most if not all of these criticisms are not true. These experiments have been repeated many times and the subjects in the original experiment did not have poor memories. But, of course, you will say, what can you expect when you learn such silly things as nonsense syllables. Let me assure you that many other sorts of materials have been used, such as lists of words, stanzas of poetry and selections

of prose, and invariably one has obtained similar results. It does not make any difference what materials one uses, forgetting takes place just as rapidly. And some of you may say, "But the material was tested by relearning rather than recall." And, on this point, I can assure you that the relearning which was employed will give a much better score than a simple attempt to recall. If these learned materials had been tested by recall, the results would have shown an even more rapid rate of forgetting.

But you will say, "I do remember things better than these results would indicate." Of course, this is true and the answer is to be found in one condition of the experiment. The important thing is that these materials were learned only to the point of first errorless repetition. In other words, they were just learned and no more. And you will find that if you just learn material, it will be forgotten quite as rapidly as the Ebbinghaus results would indicate. Many other experimental results on learning and forgetting indicate, however, that overlearning is necessary for more permanent retention. And these experiments show that a relatively small amount of overlearning brings enormous dividends in slowing the rate of forgetting.

One reason, therefore, why there is so much forgotten is because you have not sufficiently overlearned what you want to remember. How frequently does the school child say, when he has once succeeded in spelling a word correctly, "Well, I have that," and then turns to something else. And if the school child stops at this point, one may expect that 40 per cent. will be forgotten by the end of 20 minutes and 75 per cent. forgotten at the end of a week. And how often does the adult say, "I can't remember the name of the person whom I met last evening," when probably he has heard the name only once, and all too frequently, the name was not even clearly pronounced during the introduction. And how can you expect to remember where you have put your glasses when you did not even notice that you were putting them down? In other words, how can you expect to remember when there has never been learning at all, or when there has been insufficient learning?

Let me illustrate this principle of better retention as the result of overlearning with a very practical example. Many years ago I knew a gentleman who was noted for his ability to remember names—a characteristic which was of great value in his life as a politician. He quite frankly told me how he did it. It turned out that he did not have an exceptionally good memory at all. But he frankly and quite consciously set out to overlearn the name of any one whom he might meet. When introduced to Mr. Smith, he did not merely say, "I am glad to meet you," but he would say, "I am glad to meet you, Mr. Smith." And then he would say, "And now, Mr. Smith, what did you come to see me about?" "No, I do not believe that I can help you there, Mr. Smith." And so on, so that, within a few minutes' conversation he had repeated the name ten or a dozen times. It was this repetition —this overlearning—which enabled him to remember the name, not the fact that he possessed an exceptional memory.

Our time is too limited to discuss all the other many aids to remembering. But besides the principle of repetition and overlearning which I have emphasized, unquestionably the other most important factor is the formation of associations. By this I mean that any idea to be readily recalled must be associated with other ideas. It is the idea which stands alone and which has never been associated with other ideas that is at once forgotten. And conversely the idea which is hooked up with a great

many other ideas; that idea, in other words, that has entered into a rich constellation of associations with many other ideas—has far the best chance of being recalled when you want it. Let me illustrate with a practical example.

How many of my listeners can tell me who was elected Vice-President during the Harding administration? I suspect that not many of you can answer offhand and I also believe that not many could tell me at all no matter how much time I gave you to think about it. And what when I remind you that the Harding Vice-President was the late Calvin Coolidge and that Mr. Coolidge became President when Mr. Harding died while in office. Of course, now that I have reminded you, you will recall many things about this—how Mr. Coolidge's father swore him into office and all the rest of those dramatic incidents. There is no question of your remembering Mr. Coolidge as President, but you had forgotten him as Vice-President. This difference has its basis in the very fact that you had few associations with him as Vice-President and many associations connecting Mr. Coolidge with the Presidency. This is the psychological basis of all the variations of the joke about Vice-Presidents.

I can illustrate this principle of the importance of associations for permanent memory by describing a demonstration which I give to my classes each year to emphasize this fact. The class prepares a list of 30 common nouns. My assistant comes blindfolded into the room and the list is read to him just once—allowing him several seconds for each word. Immediately afterwards he will repeat the list forwards or backwards, give the position of any word in the list or the word for any position. For several years my assistant has done this without error, and it happens that this assistant has normally such a poor memory that he always carries a pad of paper with him on which he writes everything that he wants to remember during the day. The trick is accomplished by means of the assistant having a memorized list of thirty key words which he uses time after time. This list is so overlearned that he knows each word and its position in the list very thoroughly. Let us say that his third key word is "car" and that the third word in the list which the class has prepared is "elephant." My assistant will promptly associate his key word with the class word, usually in some bizarre fashion if possible. For example, he will see an elephant inside a trolley car. Later some one asks for the third word. My assistant knows that his third key word is "car" (because he has overlearned the key list) and he sees, in his mind's eye, the elephant in the car. With this associated cue he is then able to say "elephant." I have said that my assistant recalls the 30 words by the trick of forming associations between the words in his key list and the words of the class list. I then ask the class to reproduce the list, obviously without these associations—and I have never yet found a student who could do it, although the class has been making up the list and looking at it for probably a half hour. And there is nothing remarkable in this trick of my assistant. I can assure you that any one of you could do this trick within 24 hours if you were merely willing to take the time to prepare a key list and then take the time to overlearn it very thoroughly.

Let me give just one more example of the importance of associations for remembering. It happens that I am addicted to the reading of detective stories. In a recent story, it was important that one of the characters as well as the reader must remember a certain house number but not particularly important that the name of the street be recalled.

The character in the book receives a phone call sending him to this house, the number of which is "52." He is told over the phone, "Go to number 52 and remember that there are 52 cards in a deck and 52 weeks in a year." This is good psychology. The character and I both remembered the number, but I am sure that I have forgotten the name of the street.

I have talked of only two factors which are of importance for permanent remembering. There are many other factors but they are certainly of less importance. I can assure you that these factors of the formation of associations and of repetition until a material is not only learned but overlearned can not be overemphasized if you want permanent retention. And I can assure you that these principles are equally applicable to any age. Be you young or be you old, if you want to remember something, repeat it over and over again, adding as many different associated ideas as you can even after you are sure that you know it. In this way you will probably not improve your memory, but you will certainly be able to retain and to recall things ever so much better, which, after all, is what is important in the practical situation.

IS OUR CLIMATE CHANGING TO MILDER?

By J. B. KINCER

CHIEF, DIVISION OF CLIMATE AND CROP WEATHER, U. S. WEATHER BUREAU

In the latitude of the United States, we have certain very definite and regular temperature changes. One of these is the diurnal or daily march, with the minimum occurring on the average about sun up and the maximum at 2 or 3 o'clock in the afternoon. The difference between the lowest and the highest of the day is normally about 20 degrees. There is still another periodic or regular variation in the temperature with which we are all familiar—the annual march. The coldest month of the year is, on the average, January, and the warmest, July at most places. Variations in the annual range, that is, the difference between the average temperature for the coldest and the warmest month of the year, are greatest in the northern states and least in the southern. In North Dakota January, on the average, is about 62 degrees colder than July, while for Florida the difference is only 22 degrees. The range is least along the Pacific coast; in San Francisco January is less than 9 degrees colder than July. These periodic changes in temperature are due, of course, to the relative positions of sun and earth—that is, they are astronomical in character.

Other temperature changes, not so obviously of solar influence, are familiar also. We have short-period fluctuations in which different kinds of weather come and go in comparatively brief, alternating spurts, as it were, or with short periods of irregular length—sunshine, then rain; cool or cold, then warm—succeeding one another with a regularity that every one takes for granted. However, an exhaustive statistical examination of these short-period changes fails to disclose any regularity that affords a basis for forecasting future weather independently of the standard forecasting methods of the Weather Bureau, in which daily synoptic charts play an important rôle.

In addition to these short-period fluctuations, we have long-time trends in temperature. Perhaps most of you

either have expressed the opinion personally or heard it expressed by others, that our climate is changing—that it is becoming warmer, despite an occasionally severe cold wave in winter or an untimely and unwelcome frost in spring or fall. With "Grand-dad" insisting that the winters were colder and the snows deeper when he was a lad and most of the rest of us realizing that in recent winters we have not been getting our full quota of cold weather, as measured by bygone standards, it was decided to make a rather exhaustive study of the question. We believe you will be interested in some of the results this study has disclosed from the records up to and including the year 1933.

We might give a few illustrations of recent abnormal warmth. An examination of the temperature records for Washington, D. C., shows that for the last 21 winters 18 have been warmer than normal; that every one of the last 13 was mild, and that the warmest winter of record, going back considerably more than a century, was that of 1931–32. In passing we might mention that this is in marked contrast with "Grand-dad's day," say from 1854 to 1873, when 75 per cent. of the winters were colder than normal; the winter of 1855–56 was the coldest in more than 100 years. The record for New Haven, Conn., shows that every one of the last 10 winters has been relatively warm; also, 18 of the last 21, and 33 of the last 45. This New Haven record, by the way, goes back to near the close of the Revolutionary war. Further west, we pick up, at random, the Saint Louis record, which shows 13 of the last 15 winters with above normal temperature. By normal, we mean the long-time average.

When we examine the records for other seasons of the year, such as the spring and fall, similar conditions are disclosed. For the spring (March to May, inclusive) we find in the case of New Haven that 20 of the last 24 springs were relatively warm, which contrasts sharply with the 10 successive springs from 1866 to 1875, every one of which had a mean temperature below normal; the Washington, D. C., record shows only 8 springs with below normal warmth during the last quarter of a century. In Saint Paul, Minn., more than 75 per cent. of the fall seasons for the last 43 years have been warm, in contrast to the 37 falls from 1840 to 1876, inclusive, during which only 9 were warmer than normal. Here in Washington, only 4 of the 25 falls since 1907 have been below normal temperature. The Weather Bureau maintains about 5,000 weather stations scattered throughout the country and the records for these we have mentioned are typical of others over the central and northern portions of the United States east of the Rocky Mountains.

In view of these facts, is it any wonder that people are asking the question "Is our climate changing?" It might be stated, however, that the abnormally warm weather experienced in general for a long time past does not mean that cold periods have been entirely absent. On the contrary, the records indicate that occasional brief spells of abnormally cool or even extremely cold weather are characteristic of prevailingly high temperature trends. The lowest official temperature of record for the United States—66 degrees below zero—occurred last winter in the Yellowstone National Park, notwithstanding the winter was decidedly mild over much of the greater part of the United States. Again the past winter, or that of 1933–34, and especially the month of February, has been abnormally cold in our northeastern states, with the establishment of new low temperature records at many places. However, the area affected is relatively small, as much the

greater part of the country has had decidedly mild weather, with a large northwestern area enjoying one of the warmest winters ever known. In meteorological work the winter is considered to include the calendar months from December to February, inclusive. In other words, we have been having brief cold spells and an occasional cold winter, but at the same time mild weather and warm winters have greatly predominated for many years.

We have just contrasted the frequency of recent warm winters and springs and falls with conditions shown by the records to have obtained some 50 to 75 years ago when there was a marked tendency to colder weather. Now these long-time temperature changes are quite similar in many ways to the seasonal changes we experience every year. For our geographic location, when we compute the day by day, or week by week, average of temperature for a long period of years, we obtain what is known as the normal for that day or week. In the normal annual march of temperature the lowest of the year falls about the middle of January, called mid-winter, and the highest about the middle of July, known as mid-summer.

When the turning point is reached in mid-winter there is a very definite and regular increase in the normal temperature curve, slow at first, but becoming more pronounced in March and April, after which the rate of increase is retarded until the highest point is reached in July. However, it is only the normal or average that has this regular trend. For any single year the rise from mid-winter to mid-summer is frequently interrupted by short-period fluctuations, each a few days in length—warm, then cool, in succession. This and the fact that the rise is very gradual obscures the seasonal march, and there is a lapse of some time before we are conscious of a permanent change to warmer weather. It is finally realized, however, as the season progresses, that the cold spells are becoming less frequent and less severe and the mild ones warmer.

So much for the annual march of temperature that carries us from the cold of winter to the warmth of summer, a change requiring only a few months to accomplish. In studying the long-time temperature trends we may, for a clearer understanding of their general nature, consider that the centuries, too, have their winters and summers, just as do the years. These trends, from periods of relatively cold to comparatively warm weather, are very similar in nature to the seasonal march in temperature from winter to summer, though here the shorter-period fluctuations that interrupt the general trends are measured in years instead of by days as in the other case. When these are smoothed out, as we smooth the day-by-day fluctuations to obtain the normal annual march, we find very definite long-time trends in the same general direction for many years—that is, tending either to cooler weather or to warmer as the case may be.

Our longest temperature records in this country are for the central and eastern states and go back something more than a century. These show that some hundred years ago the general trend was receding, apparently from some undetermined higher point still further back for which records are not available, and that this recession continued, with comparatively minor interruptions, to about 1865. From this date the trend curves show a more or less steady rise up to the present time. For the last 25 years this rise has been especially rapid which has carried the curve much higher than at the point where the door was opened upon the scene by the beginning of records many generations ago. In other words the abnormal

warmth during the past 20 or 25 years has no precedent in records available for study, notwithstanding the longest go back to Revolutionary war days. The change in the trend lines from the lowest, more than half a century ago, to the present time is rather impressive. For example, the 20-year average temperature for the winter, spring and fall seasons up to 1933 are from 2½ degrees to nearly 4 degrees higher than similar averages up to 60 or 70 years ago. This is quite a difference when we are considering averages for a 20-year period comprising seasons covering 3 months each.

The records for the different seasons of the year show that the winter trends are the most irregular, with the up-and-down secondary swings of greater frequency and shorter in duration than those for the other seasons. For the spring and fall the trends have been more uniformly upward, with fewer interruptions by short cold spells.

Doubtless some of you are now ready to inquire, what about other parts of the world? Are these conditions peculiar only to the areas covered by the records discussed, or is the summer of the centuries prevailing in other countries, also? To determine this, we have examined a number of long temperature records for different parts of the world, using the same smoothing device as before. These represented Canada, France, Spain, Italy, Austria, Poland, England, the Scandinavian countries, Mexico, South America, Africa and New Zealand. They are all in substantial agreement in showing upward temperature trends for a long time past, except that some low latitude areas, especially the Mediterranean countries, were negative by indicating moderate recent trends to cooler.

We have said that something more than a hundred years ago we were coming out of a warm period apparently something like that in which we are now in the midst. If we had records covering a few hundred years still further back, doubtless some interesting facts would be disclosed. As it is, they are not long enough to cover a complete cycle, that is, from one major warm peak to its successor, and consequently, they do not afford even an inkling as to just how much longer the present warmth may continue or how much higher the trend curve may go, if any.

THE HUMAN-ANIMAL DISEASES

By Dr. DAVID J. DAVIS

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THE earliest reference to disease in any literature concerns pestilence or epidemics involving both animals and man. This was because man in primitive times lived in intimate association with the various domesticated animals upon which he was largely dependent for food, clothing, transportation and protection. Diseases common to men and the lower animals could in this way be easily transmitted.

One of the first references to a definite pestilence appears in Hebrew literature in Exodus 9: 3, where it is stated, "Behold the hand of the Lord is upon thy cattle which is in the field, upon the horses, upon the asses, upon the camels, upon the oxen and upon the sheep: there shall be a very grievous murrain." This curse was sent upon the Egyptians because they refused to heed the words of Moses. In the writings of the Greek

mythology, reference is often made to Apollo, the god of healing and father of Esculapius, who was able with his far-darting arrows to scatter plagues among both humans and animals and as easily to withdraw such influences.

The first great pestilence of which we have a definite record was the Plague of Athens in 430 B.C. Thucydides gives a vivid description of this terrible epidemic, which killed on such a vast scale that, as he states, cities were almost depopulated and great piles of human bodies remained in the streets unburied. He makes this interesting comment: "For the character of the disorder surpassed description; and while in other respects also it attacked every one in a degree more grievous than human nature could endure, in the following way, especially, it proved itself to be something different from any of the diseases familiar to man. All the birds and beasts that prey on human bodies either did not come near them, though there were many lying unburied, or died after they had tasted them. As a proof of this there was a marked disappearance of birds of this kind, and they were not seen either engaged in this way, or in any other; while the dogs, from their domestic habits, more clearly afforded opportunity of marking the result I mentioned." What this disease was has never been determined, though the subject of dispute for years. Some critics have thought it to be a form of glandular plague, even though Thucydides did not mention buboes. Others believe it to be some other highly contagious disease, possibly typhus fever. However, if birds and dogs were susceptible, it would indicate that it was some disease other than plague or typhus, for neither animal is susceptible to these diseases under such conditions. Probably anthrax would explain the facts better than any other disease known to-day. This is the first known observation on the transmission of a disease through the eating of contaminated flesh from the human to an animal. To-day, in human-animal diseases, the infection nearly always passes from the animal to man.

The second great pestilence in recorded history was "The Plague of 166 A.D.," often referred to as the "Plague of Marcus Aurelius"; also the "Plague of Galen." Both Galen and Marcus Aurelius lived at that time in Rome. Marcus Aurelius has left no record of this plague. He himself died of it in 180 A.D. Galen described it and from his writings most authorities conclude it was the same disease as the plague of Athens in 430 B.C., whatever that may have been. White, in his recent volume on Roman history, refers to this catastrophe as perhaps the chief cause of the decline and fall of Rome. He states that the empire never recovered after the enormous mortality, the disorder and confusion and the depressed mental state and loss of morale that followed this plague. Gibbon mentions it, but stresses it less than other writers.

The Justinian plague, beginning about 530 A.D. and continuing for some 50 years, was another one of the greatest catastrophies of all time. Man and animals were involved. From the descriptions available the evidence seems convincing that it was real bubonic plague, though from some of the records it would seem that more than one disease prevailed. It is possible that bubonic plague, typhus, smallpox and anthrax all may have raged at the same time. The simultaneous occurrence of several infections is a possibility that may explain many of our difficulties in identifying the true nature of these ancient afflictions.

Nearly all writers assume that these pestilences were diseases that are in existence at the present time, and hence in their studies they have attempted to identify the disease with one of our mod-

ern plagues. After a thorough study of the evidence, we are forced to the conclusion that some of these great plagues may have disappeared completely. There are two such diseases known to have occurred in relatively modern times; namely, the sweating sickness, beginning in England in the sixteenth century, and trench fever, which appeared during the recent world war. We have fairly accurate descriptions of both. So far as we know, neither exists anywhere to-day.

Comparative medicine may justly lay claim in a very definite way to one of the great men of history, the Roman poet, Virgil. He has been pronounced the world's greatest veterinarian. Fortunately, perhaps, he was not a trained scientific veterinarian or medical man, for if he were it might have interfered with his poetry. No medical writer has approached him in describing disease. His most celebrated description concerns anthrax, at that time in Italy a prevalent disease afflicting man and many lower animals. Its havoc must have impressed him deeply. The sources of infection he seemed to know quite clearly and refers to them as follows: "From tainted air arose a dreadful storm, influenced by autumn's heat, and gave to death all cattle tame or wild, corrupting lakes, poisoning the grassy food." In his incomparable verse he describes various animals, revealing the different stages of the disease. He notes the young cattle, the "fawning dogs" and the sick swine. To the horse, his favorite animal, he devotes some of his finest art. He tells how the bull and the oxen in the fields are stricken. Then the wolf, the deer and the flying stags and "in the sea all swimming things like shipwrecked bodies float washed by the waves." Even the viper dies and the birds infected by the wind fall and "leave their lives in the lofty air."

Finally coming to man, he gives the first description on record of wool sorters' disease or pulmonary anthrax. He evidently was aware of the persistence of the disease in the soil, due, as we know now, to the anthrax spores. For he says, referring to the dead animals (quoted from Fleming),

> Tell men dig deep and bury them in earth
> The skins are useless, nor the tainted flesh
> Can water cleanse nor raging fire subdue;
> Nor is it possible to sheer the fleece,
> So damaged with disease and filthiness;
> Nor can the weaver touch the putrid web.
> But should a man attempt the odious garb
> With burning pimples and disgusting sweat
> His limbs are seized, and in no lengthened time
> The fire accursed consumes his poisoned frame.

No doubt we must grant to Virgil the poet's license in liberal measure. But making due allowance for this we observe there is much solid information, indicating that these human-animal diseases were widely prevalent and recognized as directly transmissible from animals to man.

Not only in these ancient times but continuing down through the dark and the middle ages, the literature is replete with references to the diseases common to man and animals. The idea was prevalent that some general cause was responsible, such as tainted air, storms, earthquakes, etc., all more or less determined by the gods. Here and there, however, we note the growth of a more definite scientific conception of a direct transmission from animal to animal or from animal to man.

In our present day we are still confronted by these same problems. Just now there seems to be an especial danger threatening man from several diseases of the lower animals which serve as reservoirs for the infecting agent. Undulant fever, psittacosis or parrot fever, tularemia or rabbit fever, fish tapeworm, septic sore throat, sporotrichosis and actinobacillosis are some of the more modern ones which we fear. Rabies, bovine tuberculosis, anthrax, glanders,

actinomycosis and bubonic plague are the more ancient diseases of this type. More and more attention is being directed to them. While some are very old, others are new or at least only recently recognized. Some seem to have been rare in the past, but at present are rapidly spreading. Practically all are carried from lower animals to man; almost never is the reverse true.

Our domestic animals play the most important rôle in transmitting these diseases. Fortunately, wild animals are less often involved. When infected, however, the latter, owing to the difficulties of control, present extremely serious problems.

Man is infected both directly and indirectly from animals. Direct and intimate contact is common and in some diseases like glanders and parrot fever is the usual route of infection. In other diseases ingested food products, including milk and meat, are the usual or almost exclusive mode of transmission. Bites are responsible for transmission, especially in insect-borne infections. For certain dangerous organisms the soil is the chief reservoir from which in different ways the germs infect animals and man. At times the routes of transmission are exceedingly devious and difficult or impossible to trace.

There are many human diseases whose transmission and control can be understood only through studies on lower animals. Such studies include experiments on normal animals and observations on sick animals. As examples, may be mentioned septic sore throat, rabies and undulant fever. Septic sore throat occurs in epidemic form, at times affecting hundreds of persons at once. It arises from drinking milk from cows whose udders are infected with a dangerous germ, the epidemic streptococcus, which enters through the teat from the milker. Mastitis or infection of the udder is a very common disease of cows, but fortunately most of these infections are not dangerous to man.

Undulant fever is common to several kinds of domestic animals and is transmitted to man either by contact or through the use of animal food products. Formerly we considered it rare, but now we know it to be wide-spread. It is one of the major health problems involving both humans and domestic animals. In its solution, as in the solution of most of these animal-human diseases, the cooperation of the veterinarian with the physician is necessary.

Rabies continues to be too common. Even the very rare case should always be considered a threatening menace to both human and animal species.

Tularemia is widely distributed in the animal world and is caused by a small bacillus. In this country human beings are infected chiefly from the rabbit. Hence we see it mostly in hunters, butchers and in women who prepare the carcasses of this animal for food. A primary lesion appears on the exposed part, commonly the hand, from which the infection spreads to the neighboring lymph glands. It is usually not a fatal disease. A campaign of education and proper warnings conveyed to persons exposed should do much to control it.

Swine erysipelas is an infection occasionally carried to man from hogs. The disease is rare in the United States, but in Europe it is common and a few human cases have appeared. Recently a serious outbreak of 80 cases appeared in a button factory in Virginia. Buttons were made there from the bones of infected hogs.

Actinobacillosis is a disease primarily of cattle and is similar to the well-known lumpy jaw or actinomycosis. Man is infected occasionally in the United States, more frequently in Europe for some reason. Both this disease and swine erysipelas, now rare in man, should be

carefully watched. They may be just emerging from their reservoirs in the lower animal world up into the human, where it is difficult to predict how dangerous they may be.

Parrot fever or psittacosis has several times recently gained the front page of the newspapers. It is one of the most contagious diseases known, being transmitted directly from parrots, parrakeets, love birds and several other varieties to man. It is caused by a filterable virus. Argentina has been its habitat for many years, but recently more or less of a pandemic has appeared and now it appears to be widely disseminated. California seems at present to be the chief focus in the United States because of the extensive aviary industry there.

Sporotrichosis is a fungous disease infecting man, the horse, mule, rat, dog and some other animals. While never as yet a common disease, it occurs in certain countries often enough to occasion some alarm. In France, Argentina, South Africa and the United States it has gained a foothold and isolated cases are observed from time to time. At present it does not seem to be on the increase. The fungus is apparently present in the soil or on plants in certain localities, from which sources man and animals become infected usually through slight wounds in the skin.

It is noteworthy that we now know enough to control most diseases of this group thanks to scientific studies carried on in the fields of both veterinary and human medicine for the past half century or more. As a rule the problem is to apply the facts we now know. The difficulties may be practical and due to failure to control the conditions. Other difficulties may be financial, where the cost of control is prohibitive, or an ignorant public may resent interference for one reason or another. Many of the problems are at bottom social ones and campaigns of education in both human and veterinary fields are indispensable. Nevertheless progress made in the last fifty years in both fields is nothing short of miraculous from the standpoint of disease control and relief of suffering.

SCIENCE AND INDUSTRY IN THE COMING CENTURY[1]

By ALFRED P. SLOAN, JR.
PRESIDENT OF THE GENERAL MOTORS CORPORATION

FIRST, I wish to express my appreciation, and that of my associates, for the courtesy extended by every one of you in joining us at dinner here this evening. The endorsement and support of such an outstanding group of thought and action, of Chicago and elsewhere, as is here assembled, represents in itself no small honor and should in itself carry conviction as to the importance of the message to be presented.

To-night, here at the Century of Progress Exposition, we find ourselves surrounded at every turn with the marvels of the age, made possible by the progress of science, capitalized through the instrumentality of industry. In the progress here recorded is written the lives of countless numbers who, through sacrifice, courage, conviction and the opportunity and encouragement that has been accorded them, have brought these wonderful things into being. There results a higher standard of life, social and economic, and a broader opportunity for countless millions. What we see here at the moment is the cumulative development of the past century, more particularly of the past two decades. Out of that past comes the knowledge of experience and the inspiration of achievement. Certainly a sound foundation to build a still greater future—and it is to that future that we address ourselves this evening.

What is to be the progress of science and industry during the next decades? Is there any logical reason to assume that progress is to be halted at this particular point in our development? On the contrary, have we not every right to believe that the very progress of the past insures still more progress in the future and at an accelerated rate, if we have the breadth of view-point and the knowledge of the facts to properly manage our affairs?

There is involved the possibility of still higher standards of living. There is also involved a still broader opportunity for all.

Unquestionably, the most fundamental problem before us in this country and, in fact, before the world to-day is the question of unemployment. This is true whether that problem be one of cause or effect. Is the solution in the acceptance of the principle upon which so many of our national economic policies are to-day being formulated, that to have more, we must produce less? And now comes an amendment to that principle, that we should continue to produce the old thing—we must not produce new and better things. Again, can we even imagine that the solution of this vital problem lies in the arbitrary discrimination of one industry as against another, through controlling the freedom of the individual to exchange the results of his own labor, according to his own judgment and desires? Are we to believe that the amount of useful work to be performed is limited to what it is to-day

[1] Alfred P. Sloan, Jr., President of General Motors Corporation, arranged a dinner-symposium on "Previews of Industrial Progress in the Next Century" which was held in Chicago on May 25, the evening preceding the reopening of the Century of Progress Exposition. In response to a telegram Mr. Sloan received nearly three hundred expressions of opinion from leaders of science and industry. This article gives the opening address by Mr. Sloan and a number of the statements prepared by scientific men.

and that the problem of unemployment is solved by dividing the amount of work by the number of workers, or are we to believe that the amount of work can be expanded, given the proper economic machinery to make that possible? Can we look forward with confidence and conviction that if we turn back to the principles which have made this country what it is, and which we are to-day discarding; if we eliminate all artificial barriers that have been erected; if we encourage rather than discourage; if we reward rather than penalize constructive effort in the future, as we have in the past, that we can consolidate and accelerate the processes of natural recovery that we all believe are very definitely in the making throughout the world? What can science and industry contribute to such an objective? The purpose of our discussion this evening is to deal with this question. Manifestly, the subject is a broad one. A survey of many branches of useful endeavor discloses the fact that great thought and effort is being expended and real progress effected toward what we might call bigger and better things in the not distant future. These things affect all phases of our daily lives; they indicate still broader opportunities ahead; they demonstrate that the world is in no sense finished. What we must do is to establish and then to recognize what the possibilities are; what can be done—then to direct our efforts toward that objective. We will not be true to the traditions of our great and wonderful country if we become satisfied with a static position, either in our thinking or in our action.

Unfortunately, it is possible to present this evening, in the limited time at our disposal, only a few illustrations of how science is ready to show the way and industry to blaze the trail toward our objective. The picture will be presented by leaders of science and industry who, through actual contact with the problem, speak with authority of those who know. I sincerely regret that we can not hear from so many others present who could contribute with equal force and authority.

By Dr. CHARLES F. KETTERING

VICE-PRESIDENT IN CHARGE OF RESEARCH, GENERAL MOTORS CORPORATION

THE whole world is now absorbed in a study of social problems. These problems were brought about largely by the war. The depression has had a lot to do with clarifying science and industry's part in these problems. As to what we do in the future will depend altogether upon how good a perspective we have as to what we know and what we do not know. The ultimate aim of all industry, science, government and sociology is for a better life—better living conditions; better health; better food; better government; better houses; in fact, for better everything. And these can come about only in proportion as our daily routine and activities conform more nearly to nature's laws, which we understand so poorly at the present time.

The very fact that we have a lot of trouble is the best indication of this lack of understanding. Any group of scientists and engineers can sit down and write a long list of things which can be accomplished in the future. And it can also be written down that these things will come to pass when our government, social and economic situations develop to a point where they are desirable. And when these new products are presented, if the people accept them, they then become the beginning of new industries which will absorb a great many of our unemployed.

This list which we are discussing is merely the extension of what is in evidence to-day. And of itself it has sufficient vitality to produce new jobs and

new commercial activities to pick up our entire unemployment. But we must do something about it. Just talking will not produce the results.

It is my impression, however, that we are on the eve of things of an entirely different nature than the mere extension, refinement and development of our present-day scientific knowledge. I feel we have upon us in the immediate future a great change in mental attitudes toward the physical world which would bring into existence new pieces of information which will completely change our scientific view-point. It is not what we know that is so important. It is what we do not know. Most of what we know can be found in libraries, in the minds of people and in process as they exist to-day. But we have no conception of what a small percentage this is to what there is yet to know.

As an illustration, we perhaps do not recognize it, but everything that ever moved on the earth has been moved by energy which came directly from the sun. Our coal and oil deposits, our forests, our crops and everything that lives on the earth is simply an energy contribution from the sun. We do not know, except in a very superficial way, how the energy which is given out by the sun is transmitted to the earth. We do not know how plants pick up this energy and convert the inanimate carbon dioxide and water into the vital materials so necessary for our existence. This, when understood, will open up an entirely new conception of things that can be done.

It is not difficult with this information in hand for even the most unimaginative person to predict the propulsion of airplanes by radiated energy with the power plants located on the ground. Nor is it difficult to envision the entire system of aerial transportation which would be unaffected by fog and weather conditions in general. Most of this work is being studied to-day under the name of photo-synthesis—that is, how plants grow. And we have one research which, for want of a better name, we say is trying to find out why the grass is green. We must understand something of these processes of radiated energy before many of the great problems which lie ahead of us can be solved.

So much of our information to-day does not consist of basic understanding. It is known to us only by definitions. We say we can see through a pane of glass because it is transparent, and yet we do not know the first principle of how light is transmitted through glass. We say a copper wire is a conductor of electricity, and yet even our best scientists do not know, even in a small way, how electricity passes through one. We rub our hands together; we say they are warmed by the friction, and yet we have no knowledge to-day of the magnetism of friction. We know we have ball bearings, but as to the exact action of lubrication little, if anything is known, and in the commonplace things that are used in the electrical industry, such as magnetism, electric charges, etc., we have only a very superficial knowledge. We know these things exist, however, because we can see the effects of them.

Each year we discover new things, which a short time ago we did not even know existed. This has been true in the case of food and vitamins and other principles of nutrition. I can not help but feel that in a very short time we are going to break loose another great piece of basic information which will keep us industrially busy for a great many years to come. I think if we write down as our immediate problem those things with which we are dissatisfied we have a long list of things to do. We can make our cities less noisy; we can take dirt out of the air; we are air-conditioning our houses; we can have television and an unapproached number of other things. Now if we will go ahead and do these things which are evident, to the

best of our ability, and still keep an abiding faith in what we know and in what we do not know as having possibilities of great contributions to human welfare, there will be no need to fear the future.

There are many people who doubt if human progress can continue on its present standards. Still others think that we have to go back to lower standards of living because they see no way out of our present difficulty. There are, however, a substantial number who, knowing something of the development of civilization, do not regard the evidence presented as justifying either a static or a retrograding standard of living. Our assemblage around this table, made up of all classes of scientists and industrialists, consists of all the talents from that group of our American people who do not believe the world is finished or that we must curtail human effort and desire. But on the other hand we do believe that the only way out of our present difficulty is forward and not backward. To those of us who have spent most of our time in experimental and developmental work failure is a common thing and if we gave up the principle every time an experiment failed we would accomplish nothing. If common sense dictates that our objectives are sound, we must keep on failing and learning and failing until the objective is obtained.

Our civilization as a whole is new. This is the first time in the history of the world that such a civilization has been in existence. It in itself is an experiment, and just because we have encountered difficulty is no cause for despair. We must find out what is wrong and then remedy it, but we must not give up hope of a better and more secure life.

Almost every group of human society has been blamed for our difficulty, and the group which we represent has come in for a good measure of criticism. Most of this has come from people who do not know, either through the lack of imagination or experience, how to project the future. We welcome criticism and are open to suggestions as to how to do our work better. We feel that this depression is just one of the echoes of the great war. Nevertheless it is a reality and everybody must do what he can to help in every way possible to tide over these difficult times.

We are being told that if we develop new things we must accept the responsibility to see that they are properly used. We can not accept this proposition. First of all, we do not know when we are developing a new tool of human usefulness, and secondly a mind turned in fact-finding and experimentation does not make either a good politician or a social worker. We believe that many of the principles that have been developed in the physical sciences can be used in the study of the social sciences and we stand ready to contribute in any way that we can to this work. In the conception of any new project few people can see its significance, but when difficulties are encountered they always want to turn back. Christopher Columbus had exactly this experience with his crew, and while he did not reach his objective the result of his bold voyage resulted in a very much more important thing than that which he started out to do.

This same thing holds good in practically every human undertaking. We must believe both in the integrity of the people and in the motive which drives them on to their new undertaking. We must also have an open-mindedness in dealing with all new problems. When Faraday was experimenting on some of his first work in electricity a member of Parliament said, "What use can this ever be?" He replied, "You may be able to tax electrical apparatus some day."

This has, we all know, come true. In the short space of time between the Century of Progress of 1933 and to-night, a

great many significant steps have been made in all branches of science, industry and human relationships. These will be discussed by our distinguished guests. While no one can predict what the significance may be, we know that these new things have as great a potential at this time as any other great discoveries had in times past, at their inception. Every activity has before itself many great jobs to do. Perhaps one of them that concerns us most is with health. The doctor has done a wonderful job in his long tedious journey from the medicine man of ancient time, with his attempt to scare away evil spirits, to the present day of scientific approach and intelligent diagnosis. It will take him many years of the new century to understand all the delicate chemical reactions that go on in the human system. The physicist, the biologist and the engineer are all being asked to lend their assistance in this great work. The exhibit of medicine, surgery and general health education is one of the most important in this great exposition, in which we have a part.

Most people think that science and industry are interested only in the development of labor-saving machinery. This is entirely a false notion. But we must not forget that for the past 50 years when the great building of our railways, cities and industrial plants was going on this labor saving was a most important thing because we did not have enough people to do the work. And only five years ago we had a scarcity of labor in this country. We are all very much more interested in the production of labor-producing projects and invention than we are in labor saving, and it is our desire to present to you to-night this point of view. If you will only recognize how much there is yet to be done that will be of general good to the whole human family, then we need not worry, but we must be bold enough to take those forward steps which will bring back prosperity in any measure that we desire or in any measure which we have imagination enough to conceive.

By Dr. F. B. JEWETT

VICE-PRESIDENT OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY AND PRESIDENT OF THE BELL TELEPHONE LABORATORIES

In the field of electrical communication, with which I am most familiar, the history of the recent past and present condition of our technical understanding and the prospect of enlarged benefits in the future are such as to leave no scintilla of doubt in my mind that continued activity in research and development will be as productive of benefits in the years ahead as it has been in those of the recent past. While no one in this field of applied science, any more than in any other, can say specifically and with certainty just what can be accomplished in the next five, ten or twenty years, we do have very definite assurance of the possibilities of substantial accomplishment and of the general directions in which these accomplishments are to be looked for.

Substantially all present-day electrical communication, which has given the world its far-flung and extensive network of telephone and telegraph communication facilities by wire and radio, with its direct and indirect employment of hundreds of thousands of men and women, has been accomplished in the period since the time of the Centennial Exposition in 1876. All of it has been the direct result of painstaking research in fundamental and applied science. While the groundwork of our present structure is laid in the fundamental science discoveries of the nineteenth century, practical application of these dis-

coveries in 1876 was confined to essentially primitive forms of land and submarine cable telegraphy. Had scientific research and development in this field ceased or been materially retarded with the holding of the Centennial Exposition, electrical communication would have continued to be essentially a weak and insignificant tool in our social structure. It would have afforded little direct employment and would have been but little effective in building up and bettering our social structure.

In 1876 there was no art of telephony whatever. There was likewise no art of wireless transmission either for point-to-point, person-to-person or broadcast transmission of intelligence. There was no way possible of communicating intelligence to mobile objects, such as ships, beyond that afforded by the slow methods of visual signaling within the limited area of the visual range. There was no art of recording and reproducing sound, such as is involved in our modern phonographs and talking motion pictures, both of which are the direct by-product results of research and development work in the field of electrical communication.

In the period which has elapsed since the time of the Centennial Exposition, and particularly during the last twenty-five years, progress in the field of electrical communication and in related fields, as a direct result of scientific research and development, has been enormous. New arts of inestimable value to society have come into being, have given rise to remunerative employment to hundreds of thousands of men and women, and have added materially to the betterment of living conditions. The direct results definitely allocable to these advances through science, while enormous in themselves, are insignificant as compared with the indirect results which have followed in the train of a quick, reliable and world-wide introduction of electrical communication in all its varied aspects. If we were overnight to eliminate the results of research and development work in the field of electrical communication during the past twenty-five or even the past ten or fifteen years, the dislocation of the social and industrial structure would be appalling. Many of our everyday activities would be enormously curtailed, many of them could not be carried on at all, and vast numbers of the population now gainfully employed would be added to the army of the temporarily unemployed.

The processes by which our present-day results have been achieved through continued scientific research and development have been accompanied by a steady progress in the methods and tools by which this type of progress can best be accomplished. We have to-day, in the numerous great industrial research laboratories concerned with the problems of electrical communication, powerful weapons for attacking the problems of the future and for making full and immediate use of every discovery in the field of fundamental science which is applicable to a betterment of electrical communication. We have a vast store of accumulated knowledge and a greatly increasing amount of information as to where further effort can be applied to a betterment of electrical communication.

We know that despite all that has already been done, there are still great opportunities for the improvement, extension and cheapening of our present systems of telegraphy and telephony. We know that unless our present efforts are artificially restrained through short-sighted conclusions predicated on a narrow viewing of the current effects of the depression, we can very greatly extend and cheapen the facilities of electrical communication to the very great benefit of the entire social and economic structure. There is no sound basis for believing that achievement of these prospective objectives, through continued scien-

tific research and development and practical application of the results, will have any different effect on employment and standards of living in the future from that which has been the invariable result in the past.

In the past, in the field of electrical communication, every substantial step forward through scientific research and development has carried with it increased employment and has been in the direction of a better standard of living. Whole arts have been created to afford employment to vast numbers of people where no employment whatever obtained before. Each extension of service and each thing which has resulted in cheapening or bettering the service has likewise resulted in increased direct and indirect employment. It is inconceivable to me that continuation along the path which we have been following will carry in its train a complete reversal of these results or even a substantial modification in the effects on employment and living conditions.

By Dr. W. R. WHITNEY

VICE-PRESIDENT IN CHARGE OF RESEARCH, GENERAL ELECTRIC COMPANY

Among the future developments which immediately suggest themselves are:

Air conditioning-temperature and humidity control, in homes, offices, schools, hospitals and other public buildings; light, stream-lined, low center of gravity trains for speeds of 100 to 200 miles per hour; electrification of all railroads; trunk highway systems avoiding cities and towns and separating passenger cars from trucks; highway lighting, making high-speed night driving safe; flying at high altitude for increased velocity and economy, automatic piloting and landing control from ground; complete substitute for visual control, perhaps including micro-altimeters and micro-fathometers, for making flying and navigation safe in thick weather; home teletype by radio, giving up-to-the-minute news; home motion pictures by radio; home television for events of interest; reduction in cost of power as by mercury boiler, coal used at mine, etc.; high voltage, direct current transmission, reducing power costs and extending economic radius; new materials—improved textiles, new synthetic resins replacing wood, metals and other natural materials for many purposes; new alloys, new structural materials giving better heat and sound insulation; production of new and useful mutations and control of malignancies by x-rays; elimination of needless noise; elimination of slums, extension of parks, widening and beautifying city streets; household drudgery ended by complete electrification of every home; all routine industrial and clerical jobs made wholly automatic; increased productive efficiency, resulting in more goods for all, with greatly reduced working hours.

These items are mostly in the engineering stage already. That is, the scientific discoveries on which they are based are already at hand. Scientific work, or careful curiosity, has always disclosed unexpected facts on which new engineering is based. Almost every one of our great engineering assets was at first a mere useless scientific curiosity. This is true of gas engines and of aluminum, for example. It is true of electricity and most of its applications. For years electric welding (which now accounts for miles of pipe lines) was largely a curiosity. Radio, itself, was unforeseen and is the result of scientific curiosity, while radio tubes, for generation and for reception, were not anticipated, but discussed as novelties of science.

Moreover, we ought to expect science to start even more wide-spread engineering developments in the future than in

the past, because there are widely spreading fields and more distant areas in which the inquisitive are now working.

Certainly one can not foresee or predict the particular new science disclosures of the future. They have usually been unneeded for a while, even after disclosure. In other words, we have to get the assets and then apply them before they possess real value. Judging from history, we can expect continuing changes in engineering development as long as inquisitive men are at work and we can not foresee them any better than men foresaw steam engines. This principle of discovery first and utilization after is the oldest thing in man's history.

I have seen a tiny electric motor running directly by sunlight. A Jules Verne might picture the advantages of every one having a powerful helio-electric center in his back yard, but that is not a fair use of science in this case. It only serves to show how much we still have to learn.

Science to-day is smashing atoms, transmuting them into other elements, transforming matter into energy and discovering new fundamental things, such as the positron, the neutron, the deuton, and now the triton. No one can foresee the applications of this new knowledge, but the electron brought us long distance telephony, radio broadcasting, talking pictures, television and scores of useful automatic controls. Surely from its newly discovered colleagues we may confidently expect in time applications of equal or greater importance.

Since the stone age, men have thought the world was finished, but history shows that only one thing is certain—change.

By Dr. ARTHUR H. COMPTON

PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO

THE scientist is society's scout who goes far into nature's new territory and brings back a report of what lies there. Almost every new wave of technological advance has followed upon some important new discovery by these scientific scouts. The studies by Watt and Carnot of the properties of steam ushered in the first great era of mechanical power. The discovery of electromagnetic induction at the beginning of the century of progress which has just passed made possible the electrical industry with the great changes in living which that has implied. In the discovery of electrons and their emission from hot wires was born that vigorous youth, the radio industry. Such examples are sufficient to indicate that with further advances of science new industries may be expected to arise which will change our mode of life, much as our present way of living differs from that of our grandfathers.

Contrary to the thought sometimes expressed that the great finding of physics and chemistry have already been made, there seems no indication that our discoveries have begun to exhaust the possibilities of nature. On the other hand, techniques for making discoveries have been so developed, and the number of trained men carrying on scientific research has so rapidly increased that we may expect the next generation to see more great advances in science even than the last. The direction of science's immediate future is indicated by the lines of study which are just now being emphasized. A telescope mirror of four times the light-gathering power of our present best instrument is being constructed which will enable man to see farther into space than ever before. Great high voltage equipment is almost completed which will form a new tool for investigating the inner citadel of the new

atom where its precious store of energy is hidden. Powerful instruments are being built for observations in different parts of the world to study those mysterious visitors from outer space which we call cosmic rays. The methods of physics and chemistry which have proven so effective in their own fields are being extended to the study of growing cells with striking results.

Our telescopes and spectroscopes have shown us rather definitely the size of our vast universe. It is reasonable to suppose that we shall soon find some knowledge regarding the ancient history of that universe. Has it been in operation forever, or did it start at some more or less definite time in the ancient past? If the latter guess is correct, we may hope to learn the when and perhaps the how of that great beginning. One approach to this question comes through the cosmic rays which have perhaps been coursing through space since the beginning of the world, and may thus carry with them an account of those beginnings we are already making in the laboratory of Madame Curie and elsewhere —artificial radioactive elements. Where will these lead? Very probably to the creation of useful new forms of matter. There is a remote possibility that such experiments may lead to a new store of available energy, and if so, the magnitude of that energy should be tremendous. We do not yet know, however, whether this great store of atomic energy can be put to our use, much less can we suggest how.

In an age when available power is a problem of great importance, the possibility of synthetically preparing chlorophyll, and through its action store in chemically the power from the sun in a more efficient way than can be done through the growth of plants, is an enticing one. It would seem highly probable that physical and chemical methods of making artificial living cells will be developed. Enough progress toward understanding the processes involved has already been made to predict that this further great step is probably in the not distant future. This of course has little direct relation to life in its more complex forms, such as plants and animals. It required millions of years for nature to evolve these organisms; nevertheless, if artificial life in its simplest form can be produced, its significance in supplying man with new powers and in changing perhaps his complete mode of existence can hardly be overestimated.

Perhaps these glimpses into what the future of physics and chemistry may have in store will serve to suggest the great possibilities which are yet ahead. Unless civilization utterly fails us and removes from the followers of science the means whereby research can be carried on we may confidently anticipate a continued and rapid growth of our knowledge of nature and with that knowledge a growth of men's powers.

By Professor ROBERT A. MILLIKAN

CHAIRMAN EXECUTIVE COUNCIL, CALIFORNIA INSTITUTE OF TECHNOLOGY

THE progress of civilization consists merely in the multiplication and refinement of human wants. Leave the human spirit free for the development of science and education and no bounds can be set to the possible fullness of life of the average citizen of the United States in the coming century. But destroy the freedom of that spirit either by the blight of another world war or by the more insidious blight of what Herbert Spencer called the coming slavery—too much stateism—and the dream may be spoiled.

In my own field of physics we seen no end to the road.

By Dr. ARTHUR A. NOYES

DIRECTOR OF THE GATES CHEMICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

IN my own field, chemistry, and in science generally I feel sure that if scientific and industrial research are stimulated and not handicapped there will result in the future as in the past a stimulation of the wants of men and a much greater employment of labor than the unemployment resulting from displacement of old industries. Recent chemical research affords striking illustrations, such as development of light metals of modified steels, the numerous cellulose industries, and most strikingly in the promotion of health and efficiency through biochemical investigations. It is true there is always likely to be a temporary maladjustment of industry and employment which must be broadly handled by industry and the government if necessary. The results of failure to do so must not be attributed, as it is by some persons, to the advance of science, from which our modern civilization has largely resulted, but to industrial social and political failure to meet rapidly new situations.

By Dr. JOHN C. MERRIAM

PRESIDENT, CARNEGIE INSTITUTION OF WASHINGTON

I AM in agreement with you regarding the importance of the development of science and industry and a broad vision of policies relating to future progress. An attempt to secure a safe foundation of fact and to develop a clear vision of opportunities for the future represents one of our great responsibilities. May I express my belief in the effort to secure such understanding of our present situation and of the conditions which govern human activities that we may be able to develop policies of the most constructive type and open the way for advance with a minimum of loss and the maximum of advantage for the future.

By Dr. G. H. PARKER

PROFESSOR OF ZOOLOGY, HARVARD UNIVERSITY

BIOLOGICALLY speaking it is fair to say that man's social progress is now only at its beginning and that the two million years that separate us from the caveman mark only the start of human life; the progress of the next two million years is as inevitable as that of the last, and when we have reached this new goal such events as the present depression will have vanished beyond recognition.

By Dr. RAYMOND PEARL

PROFESSOR OF BIOLOGY AT JOHNS HOPKINS UNIVERSITY

I AM of the opinion that we are on the threshold of advances in biology generally, and particularly human biology, that will fundamentally alter our outlook. Progress in biology in the next decade, comparable in significance to that in physics in the last decade, may confidently be expected.

Already we know how in the laboratory to increase the power of lower organisms to utilize their available resources in food material and energy for vital processes, such as growth and duration of life from three to ten times over their usual performance with corresponding relative increases in size, longevity, and so forth.

Developments and applications along

these lines are likely to come in the not too distant future. Our greatest need now is for more encouragement and support of research in human biology to make possible a better social integration between human beings in the mass, and discoveries and advances in the industrial field.

By Dr. J. McKEEN CATTELL
EDITOR OF SCIENCE AND THE SCIENTIFIC MONTHLY

SCIENTIFIC research and the applications of science in the course of 150 years have increased fourfold the productivity of labor; they have doubled the length of life. Science has made it possible for each to work at routine tasks half as long as formerly and at the same time to consume twice as much wealth. Fourteen hours of labor, shared by women and children, once provided hovels, lice and black bread for most people, luxury for a few. Seven hours of labor will now supply comfortable homes, warm clothes and healthful food for all. If the resources provided by science were properly distributed—as they will be when we have an applied science of psychology—there is now sufficient wealth to enable all to share in the desirable luxuries that science has created—running water, electric household equipment, telephones, automobiles, radios and the rest—and to enjoy in full measure the most nearly ultimate goods of life—home, friends, things to do, freedom, self-respect.

The applications of science have abolished slavery and serfdom, the need of child labor, the subjection of woman; they have made possible universal education, democracy and equality of opportunity, and have given us so much of these as we have. Science has not only created our civilization; it has given to it the finest art and the truest faith. During the coming century, the advancement of science should be the chief concern of a nation that would conserve and increase the welfare of its people.

By Drs. WILLIAM J. and CHARLES HORACE MAYO
MAYO CLINIC, ROCHESTER, MINN.

THE discoveries of Pasteur and Lister have resulted in the elimination of contagious disease through preventive medicine. The average life of mankind in the time of Queen Elizabeth was twenty years. To-day the average is fifty-eight years for man and sixty-one for woman, who is biologically more important.

As the life span has increased, diseases of later life, that is, cancer and diseases of the heart and the blood vessels, have taken the major toll. Remarkable advances have been made by new methods not only in the diagnosis of cancer, but in its cure, so that the percentage of cures in recent years has been doubled. Marvelous progress has been made in a better understanding of diseases of the heart, the blood vessels and the kidneys, which to-day have been brought into the field of preventive medicine.

Much of this new knowledge has been brought about by better understanding of heredity in relation to constitutional liabilities. The scientific discoveries of to-day are becoming the handmaidens of the medicine of to-morrow.

Seventy-five per cent. of the energy produced in the human body is not under conscious control. Certain small inconspicuous glands of internal secretion, which act through the sympathetic nervous system when affected, are responsible for many of the physical and mental disorders of man.

These recent discoveries in medicine are leading to astonishing results, and give a prospect that the life of man will soon reach the Biblical promise of three score and ten.

The people of America base their hopes of sound democracy on education, so that government which now is controlled too largely by emotions may be more intelligently administered. The medical profession is one of the great forces in bringing about social progress.

By Dr. RAY LYMAN WILBUR

PRESIDENT OF STANFORD UNIVERSITY

FAR from being finished, the human family and our social organization are not even started. We have uncovered the geography of the world and are beginning to put various universal laws into service. Every time our research workers develop a new fact, new possibilities of advance are opened up. Our nation has benefited more than any other from discoveries and inventions. This is a period of readjustments following a great war. If we can preserve our liberties and retain for the individual his freedom of action and exploration into the unknown, we will find new ways to go forward.

By ALFRED P. SLOAN, Jr.

PRESIDENT OF THE GENERAL MOTORS CORPORATION

IT is tremendously encouraging to be assured by men who speak with authority that science is ready to show the way to greater industrial progress and thus to higher standards of living and greater opportunities for all.

In calling together the leaders of science and industry for our meeting on May 25, we asked two questions:

"What is to be the progress of science and industry during the next decades?"

"Is there any logical reason to assume that progress is to be halted at this particular point in our development?"

The contributions of these men who are in actual contact with the problem show that the world is in no sense finished; that great thought and effort is being expended and real progress effected toward better things that affect all phases of our daily lives. They confirm the belief that the very progress of the past insures still more progress in the future and at an accelerated rate, if we have the breadth of view-point and the knowledge of the facts to properly manage our affairs.

The assurance of these leaders that scientific progress is not a thing of the past is a challenge to America not to be satisfied with a static position either in our thinking or in our actions. It is a challenge to us to continue to encourage and reward constructive efforts and to retain the principles which have made this country what it is.

If we accept this challenge we will accelerate the processes of natural recovery that we all believe are very definitely in the making throughout the world. We will build a sound foundation for a still greater future.

MAKING THE GLASS DISK FOR A 200 INCH REFLECTING TELESCOPE

By Dr. GEORGE V. McCAULEY
CORNING GLASS WORKS, CORNING, N. Y.

To the scientist and research worker the casting of a glass disk for an astronomical telescope must seem a very simple task. One constructs a mold the size of the mirror, an annealing oven which will contain the mold when filled with glass, melts a sufficient quantity of glass in some sort of furnace, transfers the molten glass into the mold, places the mold with its load of glass into the annealing oven, and finally, depending upon the size of the article and the known annealing constants of the glass, controls the rate of cooling of the glass in the annealing oven until room temperature is reached when the glass may be removed as the desired mirror blank. At least that is how it appeared to the laboratory staff of the Corning Glass Works when the problem of making a 200 inch reflector for the California Institute of Technology was placed before them by the observatory council of that institution late in 1931. This attitude may have been born of ignorance of the dangers ahead or of a complete lack of any traditional ideas in the minds of that organization as to the proper methods for casting large telescope disks. At any rate those entrusted with the task had complete confidence in the ability of the laboratory and engineering facilities at their command to succeed. With this confidence, and armed with a full knowledge of the melting, working and annealing properties of the glass they could see no great obstacles.

The detailed accomplishment of the various steps in the process belongs more precisely to the realms of engineering than to those of the pure sciences. Since, however, the purpose of the whole endeavor was to produce a tool for scientific research, an account of the engineering problems encountered and of the regular glass industry practises employed will be of interest to all.

The forming of glass objects by melting broken pieces of glass at low temperature in a mold of ceramic materials dates from antiquity. It is not possible, however, with all types of glass to secure articles by this method clear of objectionable gas bubbles resulting from entrapped air and unsightly wisps of crystallization marking the original exposed surfaces of the individual pieces of glass. These defects are particularly noticeable with the low expansion borosilicate glasses, of which it was desired that the 200 inch disk be made. It was evident, therefore, that the disk would have to be cast from the molten state by transferring the glass by one of the many known methods of the industry from a melting unit to a suitable mold.

A mold material suitable for casting glass must possess certain properties. In the first place, it must have sufficient strength to sustain the load of the glass. Secondly, a certain degree of refractoriness is essential to withstand the temperature of the molten glass without fluxing. Thirdly, sufficient insulating qualities are needed to prevent too rapid cooling and hence excessive tensile stresses in the parts of the glass in contact with the mold during the forming process. And finally porosity of the mold serves the usual purpose in casting any molten material and especially a

highly viscous one. Without outlets for entrapped air to escape through the mold bubbles form. These increase in size by virtue of the high temperature of the glass and form "blow holes" in the casting.

The research necessary to perfect a mold material with these properties, as indeed was the case for many of the problems involved, consisted largely of finding a commercial product, which approximated the requirements and then of applying the needed modification to make it work. The mold was thus made from a commercial high temperature insulating brick which admirably possessed the qualities of strength, porosity and insulation. It was also soft enough to be sawed readily in any desired shape. By applying a simple coating in the form of a thin wash of silica flour its refractoriness was increased and to its surface was given friability which subsequently insured easy removal of the glass from the mold and incidentally prevented the evolution of small bubbles of gas from the surface of the mold after the prolonged heating following the casting operation.

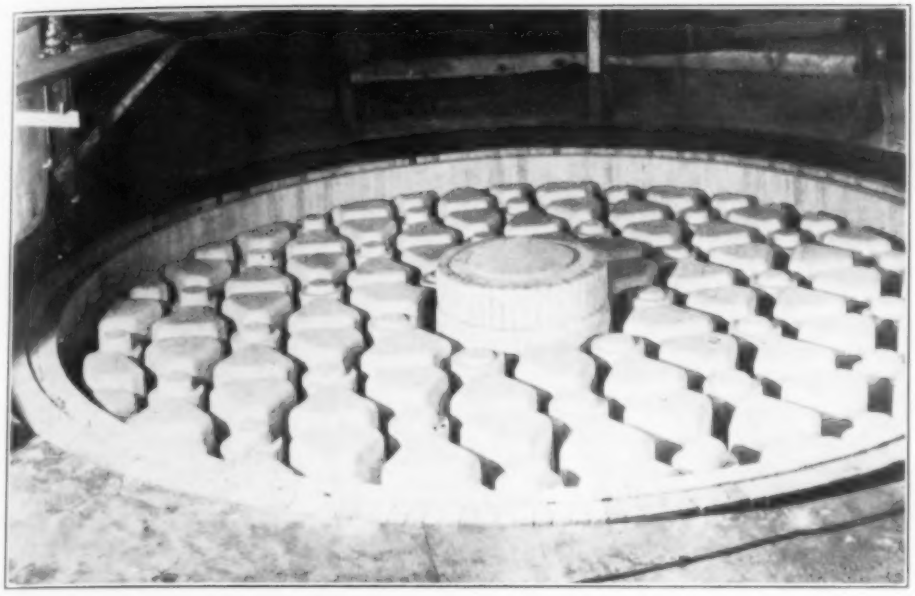
The making of the mold was somewhat complicated by a desire to obtain the requisite rigidity in the large disk with reduced weight. In accordance with the age-old tradition of making the mirror thickness one sixth its diameter, the 200 inch mirror would have been nearly thirty-four inches thick and would have weighed over forty tons. While the astronomers are very anxious for increased diameter of mirror they do not want the increased weight that goes with it. To meet these demands a ribbed structure was decided upon. This gave the required rigidity with an over-all thickness of twenty-five inches and a weight of twenty tons. The general form of this structure as seen from photographs of the 30 inch flat, 60 inch convex and 120 inch test flat which has already been cast and annealed is one at which the novice might be expected to arrive with compass and paper after learning that a regular hexagon can be inscribed in a circle with the side of the hexagon equal to the radius of the circle.

The form, however, besides suggesting an elementary theorem in plane geometry, serves several useful purposes from the standpoint of glass casting and mechanical strength. The straight ribs intersect the round ones, forming the points of support at right angles, and hence acute angles around which stresses may be high are avoided. Also the straight ribs with the points of support are in straight lines which makes for continuous ribs across the disk in three directions.

In making the mold masons became pattern makers, using blocks of ceramic material instead of blocks of wood. The cores for the mold were formed by cementing together shapes cut from bricks. With the cores fashioned they were located on the floor of the mold by means of a wooden template comprising one sixth of the area of the mold. These cores were then anchored in place with a metal plate and rod at whose lower end a spring under compression sufficed to take up the differential expansion between anchor and core during the pouring process.

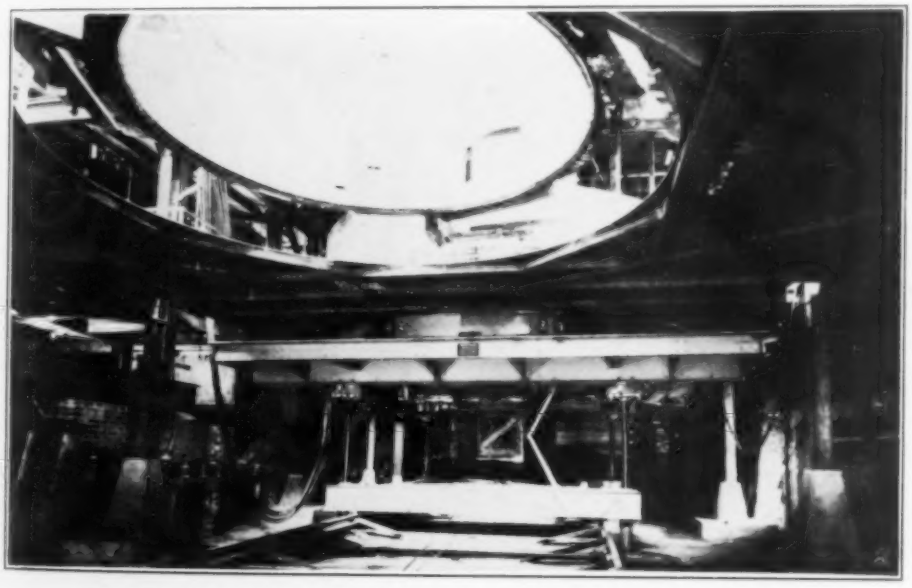
The annealing oven, while intricate in detail, is after all quite simple. It is in reality a "black body" enclosure whose walls are maintained at a uniform temperature by a system of uniformly distributed electric heating units controlled by thermocouples in conjunction with automatic temperature controllers. A simple mathematical calculation suffices to tell the power input required and hence the size of heating units to maintain a given inside temperature for a fixed degree of insulation.

To keep the power consumption of



MOLD FOR 200 INCH DISK

THE LARGE CENTRAL CORE PRODUCES THE 40-INCH HOLE REQUIRED IN THE CENTER OF THE DISK. THE REMAINING SYSTEM OF CORES PRODUCES THE RIBBED STRUCTURE TO THE DISK.



ABOVE IS THE INTERIOR VIEW OF THE POURING FURNACE

BELOW IS THE 60-TON SCREW HOIST FOR TRANSFERRING THE DISKS FROM POURING TO ANNEALING FURNACES.

annealing low the insulation of the kiln was of course given considerable attention. In its entire construction no metal passes unbroken from the interior heated portion of the outside, although the kiln, weighing many tons, is suspended by rods from an overhead steel structure to permit the insertion of the disk with its mold from below. All suspension rods are broken with an insulating medium under compression at the break. Thus the circular vertical wall and the roof of the kiln are suspended from above with fixed electrical connections to the source of power. The floor of the kiln is built under the mold on the table of a sixty-ton screw hoist with flexible electrical connections to the power supply. When lifted into position the side wall of the lower part of the kiln telescopes with that of the upper into a ring of insulating powder and completely seals the glass in the center of a "black body" furnace.

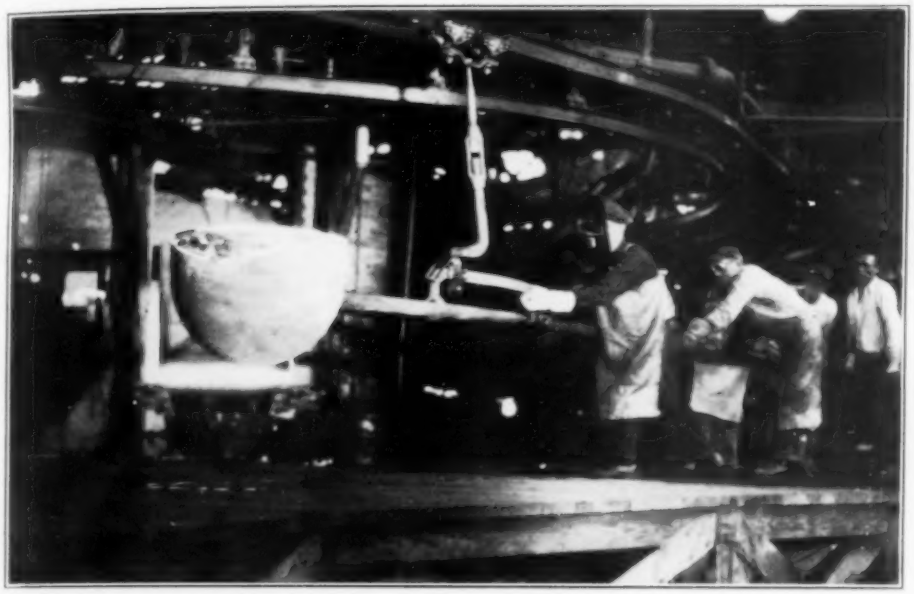
The method one employs for transferring the molten glass from a melting unit to the mold depends somewhat on circumstances of location and on the nature of the glass. When one pours a highly viscous liquid such as the proverbial "molasses of January" from the barrel to the pitcher one entraps bubbles of air in the pitcher and these do not escape readily because of the viscous state of the molasses. And so it is with the pouring of molten glass. It is very difficult to avoid introducing these bubbles; hence some provision should be made for their removal. In doing this one has the choice of either transferring the glass to the mold very quickly at a high temperature so that the viscosity of the glass after casting is still low enough to permit bubbles to rise, or to provide means for reheating the glass in the mold during and after pouring. The first plan becomes increasingly difficult as the quantity of glass to be transferred becomes greater and as we pass from the more fluid crown glasses to the viscous borosilicates because of the enormous quantity of heat that must be dissipated quickly and the increased viscosity which retards the rise of bubbles under the action of gravity. Consequently in the making of the 200 inch disk recourse was had to the second plan above.

A round furnace structure or "igloo," as it came to be called, was suspended from an overhead carriage, in a manner such that the mold could be elevated with its upper rim in contact with that of the underneath portion of the structure above. When sealed in this position the mold and hood above constituted a closed furnace which could be heated with many gas burners around its periphery to a temperature of 1350° C. This enabled any desired temperature to be maintained while the glass was being transferred to its mold and permitted subsequent heating after the mold was filled to cause the escape of all entrapped gas bubbles.

For the construction of the pouring furnace the same light, refractory insulating brick was employed as was used in the mold. This kept the suspended weight on the overhead carriage to a minimum and insured the attainment of the desired temperature for the removal of bubbles.

The carriage support for the pouring furnace provided for moving it out of the way while building the mold on the table top of the screw hoist, which likewise was movable on its carriage on the floor below in a direction at right angles to the motion of the pouring furnace carriage. Thus after transferring the glass to its mold and reheating to free from bubbles it was an easy matter by pressing a button to lower the fifty-ton load of glass, mold and bottom portion of annealing kiln, shift the whole assembly laterally with the hoist carriage, and raise into position inside the annealing kiln.

The large quantity of molten glass re-

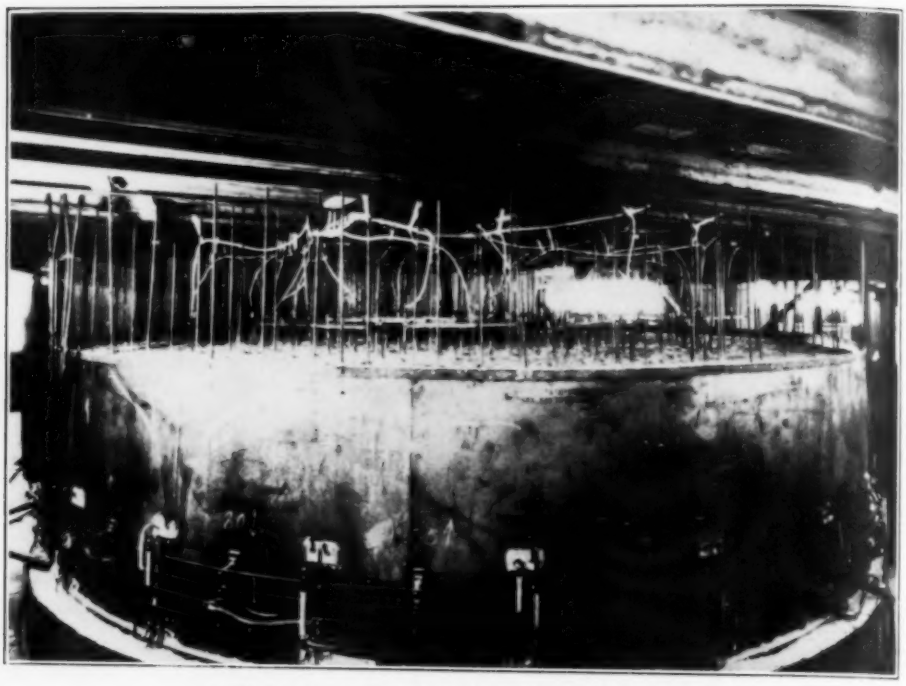


LADLE OF MOLTEN GLASS ON WAY TO MOLD

THE LADLE HANGER, TROLLEY AND BALANCING CLEVIS ARE CLEARLY SHOWN. OVER THE RIM OF THE LADLE BOWL IS THE EDGE OF CHILLED GLASS THAT SERVES AS AN ANCHOR FOR HOLDING THE "LADLE SKIN" WHILE POURING.

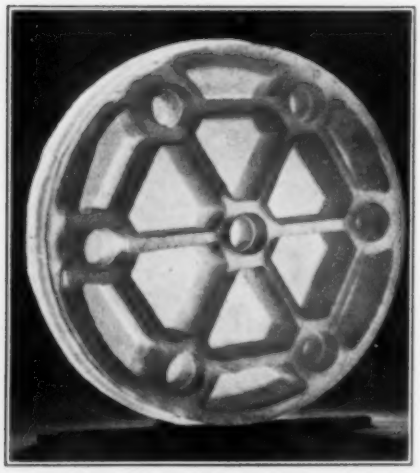
POURING FURNACE OR "IGLOO"

USED FOR CASTING THE 200 INCH DISK. THE LADLE OF GLASS IS SHOWN IN THE PROCESS OF POURING INTO THE 200 INCH MOLD.



ASSEMBLED VIEW OF THE ANNEALING KILN

WHILE THE 120 INCH DISK WAS IN PROCESS OF COOLING. THE SAME KILN IS BEING USED FOR THE 200 INCH DISK.



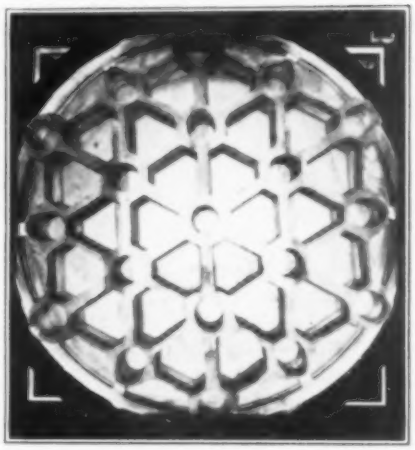
30 INCH DISK CAST ON MAY 1, 1932

REMOVED FROM THE ANNEALING KILN ON JUNE 1, 1932.

quired is best supplied from a melting unit known to the glass industry as a "tank." This is nothing more than a large pool of molten glass contained by walls of refractory clay over which a brick structure closes the space into which fuel is burned as in the open hearth furnace of the steel industry. It is possible in this manner to secure a large volume of glass of more uniform physical properties than if melted in many small pots, as has been the custom of the past in making telescope disks.

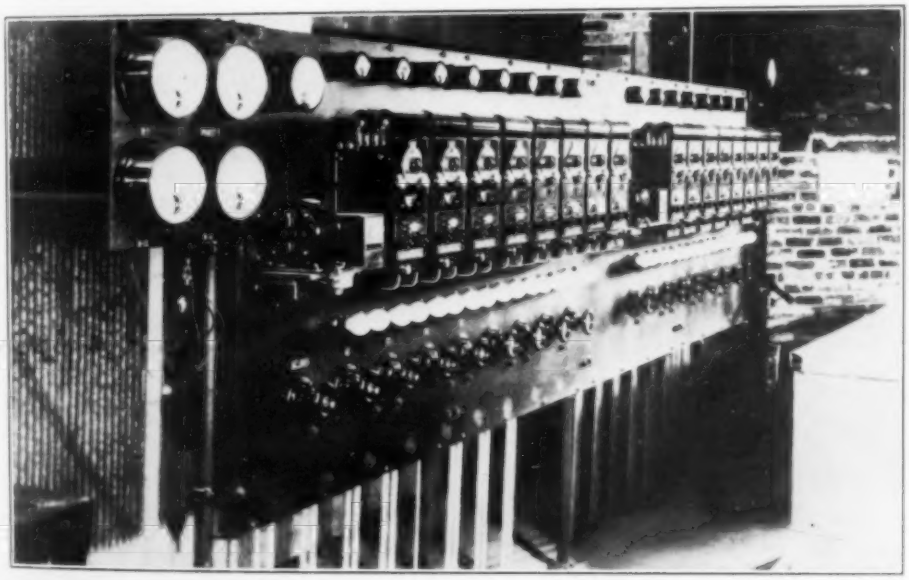
Many ways, tried and untried, might be used for conveying the glass from the melting unit to the mold. In the actual making of the 200 inch disk, the method of ladling was selected as the one best suited to the particular location, as costing less to install and operate for

the manufacture of a single disk and as having associated with it the least element of chance. This is in part an old method employed in the manufacture of window glass and was known to work well. In this process large iron ladles capable of holding approximately 750 pounds of glass are employed. A swivel hanger on a trolley carries the ladle on an overhead track for easy transference from tank to mold. At the lower end of the hanger is a second trolley wheel running in a clevis attached to the ladle handle and extending parallel with it. This clevis permits the point of suspension of the ladle system to shift with the load. When empty, balance is obtained at the far end of the clevis, and when loaded, at the near end with respect to the bowl of the ladle.



60 INCH DISK CAST ON JULY 13, 1932
REMOVED FROM THE ANNEALING OVEN ON SEPTEMBER 19, 1932.

In filling the ladles attention must be paid to the viscous nature of the glass. Passage of the ladle rim through the glass can not be hurried if one wishes to fill the ladle with a single and simple dipper motion. The ladle enters the tank in an inverted position after being thoroughly cooled with water. It is then dipped down and a slowly rotating motion imparted about the handle as an axis turning in bearings in the balancing clevis. One edge of the ladle rim thus cuts through the glass and cups out that portion of glass which fills it. The ladle

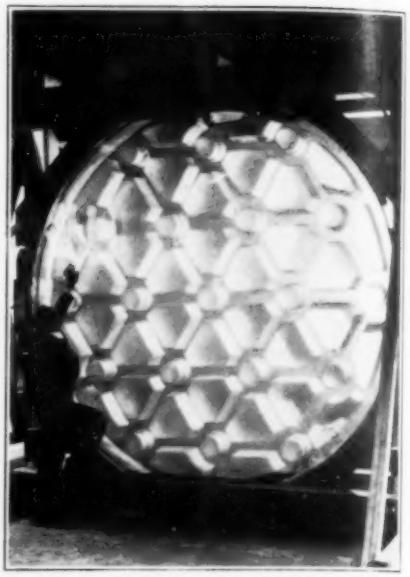


SYSTEM OF AUTOMATIC CONTROLLERS THAT MAINTAIN THE TEMPERATURE DURING THE ANNEALING PROCESS

is then returned to its horizontal position and withdrawn from the tank with the point of suspension automatically changing in the clevis. The surplus glass adhering to the entering rim of the ladle during filling is now removed, leaving enough chilled glass projecting over the rim to act as an anchor for holding the viscous "ladle skin" next to the metal on the ladle while pouring from the other rim in the mold. This "ladle skin" is then returned to the far, or filling, end of the tank to assist in maintaining the level of the glass in the tank as near the initial point as possible.

The regulated cooling or "annealing" of the glass disk is largely automatic. Temperature controllers, ten in number, hold the temperature at ten scattered points in the inner surface of the kiln at whatever value the operator sets the dials. A constant temperature of 500° C. will be needed for fifty days to relieve stresses. By decreasing the dial setting of one after the other of these instruments at three-hour intervals, the temperature of the entire kiln is then reduced one degree centigrade in thirty hours. Thus the disk is gradually cooled to room temperature when it will be ready for inspection and shipment.

With disks of 30, 60 and 120 inches in diameter successfully cast and annealed with ribbed structures and the glass for the 200-inch mirror cast into its mold, it should now seem certain that even larger disks could be made by employing the methods and equipment outlined here.



120 INCH DISK CAST ON JUNE 24, 1933 REMOVED FROM THE ANNEALING KILN ON DECEMBER 10, 1933.

THE PROGRESS OF SCIENCE

PRESENTATION OF THE MEDALS OF THE NATIONAL ACADEMY OF SCIENCES

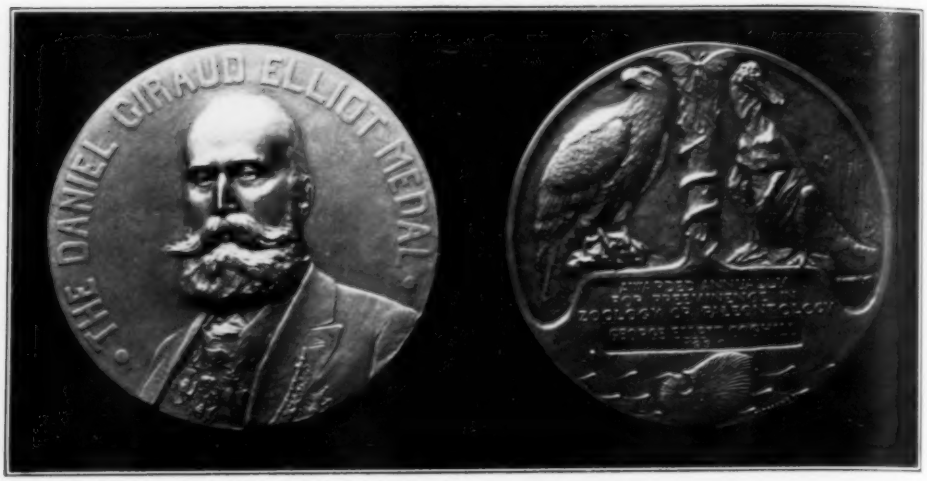
One of the outstanding events at the spring meeting of the National Academy of Sciences is the award of medals and honorariums in recognition of noteworthy accomplishments in research. The National Academy has nine "medal funds," and on the evening of April 24 it conferred honors upon five distinguished men of science. President W. W. Campbell, who gave the address at the dinner at which the medals were presented, emphasized that "the academy's ability to confer honor upon its members and others of high achievement proceeds from the honors conferred upon the academy by its members through their accomplishments in the advancement of knowledge."

Short presentation addresses by members of the academy accompanied the award of the medals. These, in part, are reproduced here:

The Agassiz Medal

The Agassiz Medal was awarded to Bjorn Helland-Hansen, of the Geofysiske Institut, Bergen, Norway, in recognition of his work in physical oceanography and especially for his contributions to knowledge of the dynamic circulation of the ocean. In his presentation address, Dr. Henry B. Bigelow, curator of oceanography, Museum of Comparative Zoology, and professor of zoology at Harvard University, and chairman of the Committee on the Agassiz Medal award, said:

In every advance in oceanography, certain names stand forth. And when scientific accounts are cast we find Helland-Hansen—often linked with his one-time master and life-long associate, Fridtjof Nansen—a key name in developments that have become integral in modern science of the sea. It was Helland-Hansen and Nansen who first clearly appreciated and published to the scientific world the fact that the oceans are so uniform over great distances and over great ranges of depth that only from the most precise measurements and determinations can the true physical characteristics of the high seas be learned. Nor was this an advance in technique only, for practise and theory marched hand in hand. And in 1909 Helland-Hansen and Nansen jointly published their classic study of the Norwegian sea, in which they so accurately traced its essential physical characteristics, with the ebb and flow of the ocean currents, as to make this at a stroke the best known part of the ocean, and their monograph a model for all the regional studies in descriptive oceanography that have followed it. In 1903 we find Helland-Hansen and Sandstrom (then young men) developing a simple and workable method by which Bjerkenes' theoretic analysis might be applied numerically to conditions as actually existing in the sea, with calculation of dynamic currents in the waters between Norway and Ice-



land as a test case. Later came Bjerkenes' monumental volumes on "Dynamic Meteorology and Hydrography," following which, and with gradual developments in mathematical method (in which Helland-Hansen's touch is repeatedly to be seen) many dynamic studies have been made for different parts of the sea. The current surveys made on the Grand Banks by the International Ice Patrol Service are a direct result of Helland-Hansen teachings. But again it awaited Helland-Hansen, working with Nansen as so often, to apply dynamic calculation to accumulated data for a great ocean, and so to make clear the circulatory tendencies existing on so broad a scale throughout the whole mile-deep mass of water.

The Elliot Medal for 1930

The Elliot Medal and Honorarium of $200 for 1930 was awarded to Dr. George Ellett Coghill, professor of comparative anatomy and member of the Wistar Institute of Anatomy and Biology, in recognition of his work, "Correlated Anatomical and Physiological Studies of the Growth of the Nervous System in Amphibia." Dr. Ross G. Harrison, Sterling professor of biology at Yale University and chairman of the Committee on the Elliot Medal, in conferring the honor upon Dr. Coghill, made the following statement concerning his work.

Embryologists have dealt for the most part with the development of organic form, disregarding the fact that with it goes hand in hand the development of activities or function. The correlation of these two phases of development, because of the difficulties involved, has not received the attention it merits. It is precisely in this field that Dr. Coghill's pioneer work has won for him a place of high distinction. The amphibian embryo, still in its envelopes, shows the first muscular movements when its external form begins to shape itself and head, trunk and tail are easily recognized. The character of these movements rapidly undergoes a series of changes during the remainder of embryonic life until at hatching they are quite complex and the young animal is able to shift for itself. The progressive changes in reaction have been followed by Dr. Coghill step by step in individual embryos, and at each stage cases taken immediately after their reactions had been tested were preserved and studied microscopically. In this way the actual state of differentiation of the nervous system in each individual has been correlated with its behavior. It has been found that a progressive differentiation of nerve cells, fibers and sense organs takes place, preceding by a short interval the initiation of the corresponding reactions. Associated with differentiation, but in a certain sense antagonistic to it, is the process of growth, the study of which has required the counting of thousands of cells and charting their positions in the spinal cord and brain at various stages of development. This has involved an immense amount of painstaking work which would all have been to little purpose, had the task not been approached by a man of broad knowledge and subtle insight. From all this has developed a new conception of the origin of nervous function. At no time does the nervous system work as a collection of independent reflexes, which later become integrated. On the contrary, at each stage it functions as a whole, expanding from stage to stage, and as development proceeds, various partial functions arise within it as more or less discrete reflexes. These investigations of Dr. Coghill will have a lasting influence in psychology and physiology as well as in embryology.

The Elliot Medal for 1931

The Elliot Medal and Honorarium of $200 for 1931 was awarded to the late Davidson Black. Dr. Black, a native of Canada, was professor of anatomy at the Peiping Union Medical College, Peking, China, at the time of his death on March 15, 1934. This award was made in recognition of his work on an adolescent skull of *Sinanthropus pekinensis* in comparison with an adult skull of the same species and with other hominid skulls, recent and fossil. In giving the reasons for the award to Dr. Black, Dr. Henry Fairfield Osborn, honorary president of the American Museum of Natural History and a member of the Committee on the Elliot Fund, said:

The honor falls to me of describing his share in the discovery and his unique part in the description according to the very highest standards of modern prehistoric anthropology, of the Peking man, *Sinanthropus pekinensis*, which has already become a classic. These additions to the great and highly diversified family tree of man were discovered in the years 1926 to 1929 in a cave fissure deposit about thirty-five miles southwest of Peiping, a deposit of very hard limestone known for many years to yield rich fossil remains of the early Pleistocene period estimated at approximately one million years ago. Infinite patience and infinite technical skill were required to free these fragile specimens from the matrix and a very high order of anatomical knowledge to correctly interpret them. From 1926 to 1934 Davidson Black has devoted his entire strength, energy and skill to exposing and examining this series, which yielded one type lower molar (1927), two adult or nearly adult skulls, six parts of adult and immature mandibles, various separate teeth, limb and girdle fragments, a wrist bone, phalanges, etc. To these remains the scientific name most aptly applies—"the man of China found near Peking." In a long series of brilliant publications, culminating in the monograph of 1931 for which this Elliot Medal is given, "On an Adolescent Skull of *Sinanthropus pekinensis* in Comparison with an Adult Skull of the Same Species and with Other Hominid Skulls, Recent and Fossil," all the characteristics of these specimens were carefully set forth, figured and described, with the result that Peking man is shown to be extraordinarily similar to the Trinil man (*Pithecanthropus*) in its form and brain size and structure, while differing most widely from the Piltdown man of Sussex not only in the beetling forehead but in the relatively massive jaw. Thus its closest affinity is to the Trinil cranium, while in its grinding tooth structure thoroughly human or Neanderthaloid.

The Public Welfare Medal

The Public Welfare Medal was awarded to Dr. David G. Fairchild, formerly of the U. S. Department of Agriculture, Washington, D. C., for his exceptional accomplishments in the development and promotion of plant exploration and the introduction of new plants, shrubs and trees in the United States. Dr. Henry H. Donaldson, member of the Wistar Institute of Anatomy and Biology and a member of the Committee on the Public Welfare Medal award, who made the presentation address, said:

This medal is awarded for eminence in the application of science to public welfare. The award was made to Dr. Fairchild: For his ex-

ceptional accomplishment in the development and promotion of plant experiments; for the introduction of new plants, shrubs and trees into the United States; and for his services of a working lifetime, which have contributed to the easy availability of some of our finest fruits and vegetables, thus adding to the wealth of the nation by opening new lines of activity to American farmers. It is to be noted that this award is a recognition of ideal aims guiding long-continued scientific activity directed to the public good.

The Charles Doolittle Walcott Medal and Honorarium

The Charles Doolittle Walcott Medal and Honorarium of $1,350 was awarded to David White, senior geologist at the U. S. Geological Survey, in recognition of his work, published and unpublished, on the Precambrian algae life of the Grand Canyon of Arizona. In his presentation address, Dr. Charles Schuchert, chairman of the board of directors of the Walcott Fund, told how, as a young fossil collector, Walcott's curiosity was piqued by finding some drift rock containing strange organic remains. Eleven years later he found identical ones and learned that they were of "primordial time." His interest thus strongly aroused led him to become the world's authority on the life and history of Cambrian times. Under Major Powell in 1882, he again found "primordial" fossils and the first traces of Precambrian life. "No one has yet found in abundance the Precambrian life that Walcott so earnestly sought," Dr. Schuchert continued, "and it was with the idea of stimulating others to realize his unfulfilled ambition that Mrs. Walcott, who helped her husband collect many a hundredweight of Precambrian algae, presented to the National Academy the fund which yields the medal and honorarium to be presented here to-night.

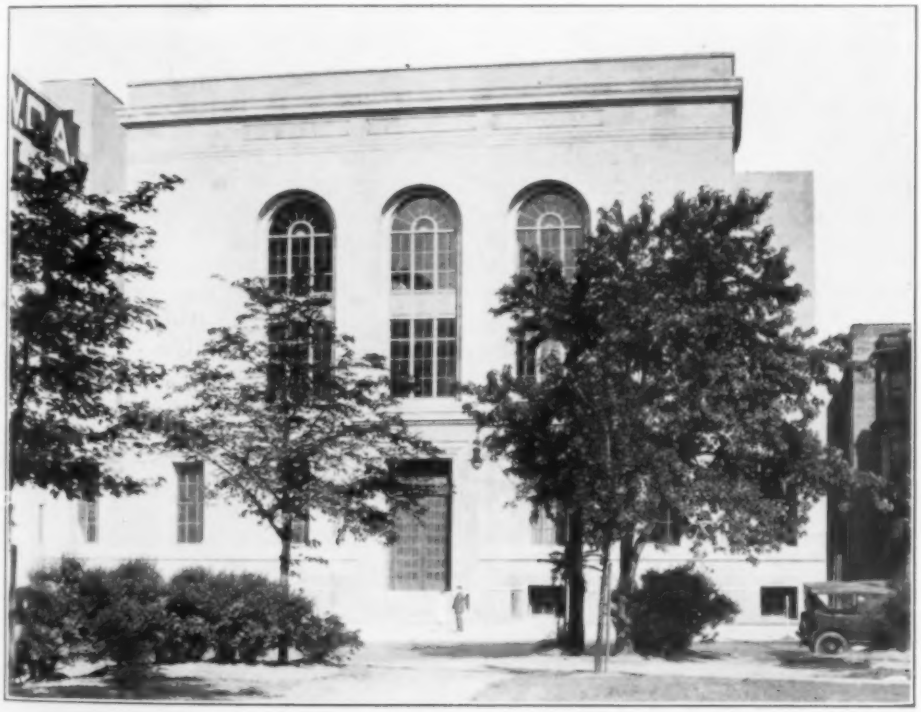
In the upper walls of the Grand Canyon occur Carboniferous land plants, which have formed the basis for one of the classics of paleobotanical literature, "Flora of the Hermit Shale, Grand Canyon, Arizona," written by David White, whose extraordinary knowledge of the coal floras has played no small part in the unraveling of our late Paleozoic stratigraphy. In the course of his work in the canyon, Dr. White's attention had been especially directed to the traces of Precambrian organisms which had been found there by Walcott and others, and which had been rendered even more significant by subsequent discoveries of similar forms in the Belt series of Montana. For several field seasons he studied with great care the detailed environment of these ancient fossils, and collected them in abundance, and he has demonstrated, with his customary thoroughness, that the deposits in which they were entombed were those of a shallow sea, and not, as had been supposed, those of a fresh-water lake. What is even more significant, he has, by new methods of laboratory research, both of a physical and a chemical nature, revealed the microstructure of these remains and established them definitely as algae. His preliminary results have already appeared in a number of papers, and his monograph, to be published by the Carnegie Institution of Washington, will bring together his studies on a great mass of material, much of which was collected by Walcott. His researches thus mark a decided step forward in our knowledge of Precambrian life.

THE PRODUCTS OF INDUSTRIAL CHEMISTRY AT THE NEWARK MUSEUM

THE dramatic manner in which the products of the chemist's test-tubes are supplanting the familiar materials of the world about us is the subject of an exhibit which the Newark Museum opened to the public at the end of March under the title "Miracles of Chemistry: New Discoveries for Industry and the Home." This is the twentieth in a series of industrial exhibits which the Newark Museum has presented dramatizing the achievements of the industries of its community, but because of its scope and timeliness has already attracted wide interest.

The exhibit which fills the entire second floor of the museum and part of its first floor has been planned to reveal the many ways in which chemistry has affected every-day life, so that the average person may be led to appreciate the tremendous and vital rôle which chemistry plays in the modern world. It was considered particularly appropriate to present such an exhibit in the Newark Museum because chemistry comprises the largest industry of New Jersey and because of the hundreds of new chemically created products, such as the plastics, the rayon and other synthetic textiles and new metals, which have found a place in modern life.

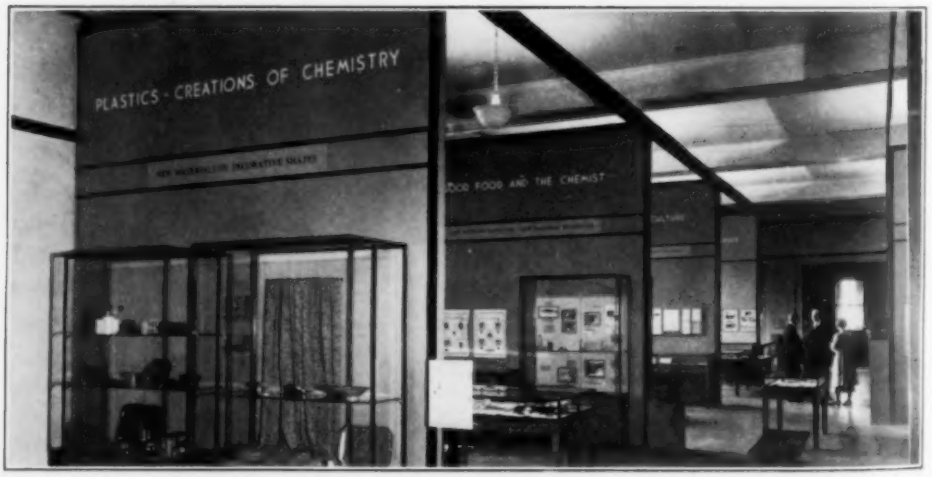
In planning the exhibit, the museum had the active assistance of a number of men and institutions prominent in the field. These included Dr. William T. Read, of Rutgers University; Dr. Edward C. Worden, of the Worden Laboratory and Library; Dr. John H. Schmidt, chairman of the North Jersey Section of



THE NEWARK MUSEUM

the American Chemical Society; Williams Haynes, author and editor of chemical publications; the New Jersey Agricultural Experiment Station, and others.

More than four thousand objects, lent by approximately 100 firms, are on display in the exhibit, all of which relate to the history or background of industrial and research chemistry. A rare and interesting collection of old books and prints dealing with the medieval alchemists and the early pioneers of chemistry, which have been lent chiefly from the University of Pennsylvania's Edgar Fahs Smith Memorial Collection, is shown in the opening section of the exhibit. Here are also seen in interesting contrast an assemblage of some 250 new chemical products of commercial value which have been developed since 1931. These "children of the depression" are eloquent testimony of the unflagging persistence and ingenuity of the chemist in seeking new, better and cheaper ways of providing the necessities of life. Plastics, dyes, perfumes and food materials are found among these



newest chemical creations. Colorful background to this part of the exhibit is given by a display of a striking selection of the new synthetically produced textiles.

On the stairways leading up to the second floor are cases showing the chemical processes involved in the manufacture of soap, sulphur, radium and aluminum.

Symbols of the chemist's most familiar operations and graphic illustrations of the basic theories of the science are seen in the south entrance to the second floor of the museum's exhibit. Adjacent to this section is a demonstration laboratory, fully equipped for performance of simple and striking experiments. The laboratory is manned by four professionally experienced chemists, headed by Emil W. Roth, a former member of the chemical faculty of the University of Heidelberg, whose duties include the performance of the demonstration experiments and the conduct of groups about the exhibit.

Upon information supplied by Dr. Read the next part of the exhibit is devoted to summarizing the facts concerning New Jersey's chemical industries. The state has an annual output of approximately $770,000,000 in silks, rayons, paints, varnishes, dyes, synthetic leathers and other chemically produced goods, the exhibit points out by means of large charts. Second only to New York, which exceeds it by virtue of the nitrates produced at Niagara Falls, New Jersey has an annual output more than twice as large as the chemical exports of Germany.

Sections devoted to treasures unlocked from coal and from cellulose follow next. In the coal section are displayed the plastics, the explosives, medicines, dyes and perfumes and other derivatives, while the story of the rayons reveals how, by studying the physiological processes of the silkworm, the chemist has produced a wealth of new materials. The New Jersey Agricultural Experiment Station at New Brunswick has contributed displays concerning the chemistry of agriculture in the next section, while nearby is a section on the chemistry of foods and the story of vitamins and the preservatives.

Perhaps the most dramatic revelation of the many ways in which chemistry has invaded the home has been made in the handsomely furnished living room, designed and decorated by Paul T. Frankl, the well-known interior deco-

rator of New York City, in which chemically created, man-made materials have been employed practically throughout. From a table and desk of Formica with stainless steel supports, to rayon curtains and a synthetic fabric upholstery, and waxed linoleum on the floor, the room gives dramatic proof of the omnipresence of the products of the test-tubes. A kitchen completely equipped, from stainless steel sink to copper pots and enamel kettles by chemically treated materials, is another illustration of the importance of chemistry in the home.

A catalogue entitled "Chemistry Changes Our World" has been published as a guide to the exhibit. In the preface, Miss Beatrice Winser, director of the museum, explains the policy. A popular and entertaining article by Williams Haynes, the well-known writer on chemical subjects, is also part of the catalogue and contributes materially to its value. The exhibit, "Miracles of Chemistry," will continue at the Newark Museum until the end of June.

RUSSELL NEWCOMB

THE "CHEMICAL" ROOM

THE MANNER IN WHICH THE PRODUCTS OF THE CHEMIST'S TEST-TUBES ARE SUPPLANTING THE FAMILIAR MATERIALS IN THE HOUSE IS ILLUSTRATED IN THIS MODERN LIVING ROOM, WHICH IS PART OF THE EXHIBIT. NEARLY EVERY ARTICLE OF FURNISHING IS CHEMICALLY PRODUCED. THE DESK AND TABLE TOP ARE OF A MOLDED PLASTIC OF A LUSTER AND SMOOTHNESS ESPECIALLY ADAPTED TO THE PURPOSE. THE CURTAINS ARE OF RAYON MATERIALS, THE HANGINGS OF AN ITALIAN BATIK WHICH IS ENTIRELY CHEMICALLY PROCESSED. THE WHITE LEATHER COVERINGS OF THE FURNITURE ARE TREATED WITH A CELLULOSE VARNISH TO MAKE THEM WASHABLE.

THE DROUGHT OF 1934

By the close of May, 1934, the most extensive drought in the climatological history of the United States had developed in the central valleys, the Lake region and the Northwestern and Western states. In fact, deficiencies in moisture, ranging from unprecedented dryness over large areas to a decided need for rain in others, was prevalent by the first of June over approximately three fourths of the United States from New York, western Pennsylvania, West Virginia and central Tennessee westward to the Sierras of California and the Cascade Mountains of Washington and Oregon.

In the Northwest the serious shortage in sub-soil moisture and surface water supplies is the result of an accumulated deficiency in precipitation covering several years. In fact, the general rainfall trend in this area has been downward for about a quarter of a century, culminating in the present drought. Every one of the past five years, up to 1934, had less than normal rainfall and the amounts for the first five months of the present year have been the smallest of record in most northwestern sections.

From this northwestern area the drought spread westward, southward and eastward to the Appalachian Mountains on the east, Tennessee, northern Arkansas and Texas on the south, and the Great Basin on the west. The 1930 drought spread from the East-Central states westward to the central valleys, and at the same time much of the area farther west had abundant rainfall.

The 1934 drought is very unusual in several respects. Seldom does a severe drought begin so early in the year and in no other case of record has one at any time covered such an extensive area.

May was extremely dry, the Ohio Valley and Lake region having less than one fourth to a little more than a third of normal rainfall for the month. It was the driest May of record in Ohio, Indiana, Illinois, Iowa and South Dakota, and the second driest of record in Kentucky, Minnesota, Nebraska and Montana. For example, the average rainfall in Ohio this month was considerably less than an inch, and the previous driest May of record had twice as much.

It was the driest spring (March–May) ever known in both the Dakotas, Minnesota, Nebraska, Iowa and Illinois, and the second driest of record in Ohio, Indiana, Wisconsin, Missouri and Kansas. North Dakota had little more than an inch and a quarter of rain during the three spring months; the previous low record—2.15 inches in 1901—is nearly three fourths greater than this.

Considering an entire year, from June, 1933, to May, 1934, it was the driest similar period of record in Indiana, Illinois, Missouri, Iowa, Wisconsin, Minnesota, both Dakotas and Nebraska, and the second driest in Ohio and Michigan.

Extremely high temperatures during May in the interior valleys and the Northwest intensified the effects of the scanty rainfall; not only on a number of occasions were the previous high May records of temperature broken, but over considerable sections it was the warmest May ever known.

From our knowledge of climatology there is no reason to believe that the 1934 drought in the Northwestern states, where most serious, constitutes a permanent change to desert-like conditions in that area. We know there have been major climatic changes in geologic times, and that large areas of the United States have moisture conditions at present differing greatly from those prevailing a great many centuries ago, but certainly no major permanent change in climate has taken place within the last few years.

On the contrary, our longest rainfall records indicate that the 1934 drought in the Northwest is but what may naturally

be expected to occur at comparatively long intervals of 30 to 40 years. These records show that quite similar periods of years, with markedly deficient rainfall, covered the ten years ending with 1864 and again the ten years ending with 1894. About midway between these were a number of successive years with comparatively abundant rains, and there is nothing at this time to indicate that history, in this respect, will not repeat itself with a return to another temporary period, not now predictable, when much heavier rains will again be the order of the day.

However, there is one feature of our present-day agriculture in the areas where rainfall is normally small, such as the Northwest, that has served to intensify the damaging effects of these severe droughts recurring at long-time intervals. In the present case severe dust storms have greatly aggravated the situation and the frequency and intensity of these unquestionably are due, very largely, to the comparatively large amount of land put under cultivation in recent years as compared with that in previous droughty periods. The greater the surface of loose, pulverized soil exposed to the wind, the more frequent and intense will be the dust storms and the more damaging the droughts. The answer to this feature of the drought question is, of course, more natural vegetation, more lands maintained in grass, with not too close grazing, and fewer cultivated fields. In this way, and this only, can man do aught to prevent or mitigate the effects of these inevitably recurring droughts.

The amount of damage by drought to the several staple agricultural crops depends not only on lack of moisture, but also the season in which the drought happens to occur. Most crops have a critical period of growth during which they are affected by the weather more than at any other stage of development. Thus, pastures, hay crops and the small grains, such as oats, rye, barley and wheat—especially oats and spring wheat—require favorable weather in spring and early summer, while corn is most affected in the midsummer season during and just following the tasselling and silking stage. Most droughts develop in summer and, consequently, corn is more frequently affected than the small grains.

The 1934 drought developed early, and hay, pastures and small grains are the principal crops affected so far. In the drought area, oats and spring wheat have been severely damaged; pastures are the poorest ever known, and the hay crop will be extremely short, regardless of future weather. Also winter wheat has deteriorated steadily, and the season is now too late for help in the southern part of the wheat belt; harvest has begun already as far north as southeastern Kansas. Corn still has a chance for a good crop if rain comes soon. The first week of June brought very helpful moisture to parts of the northwestern Corn Belt, but much late-seeded grain in other sections still lies dormant in dust at the time of this writing, June 8. This must germinate soon to mature grain before danger from frost next fall.

J. B. Kincer,
Chief, Climate and Crop Weather Division, U.S. Weather Bureau